The

Kentucky Geological Survey

WILLARD ROUSE JILLSON
Director and State Geologist

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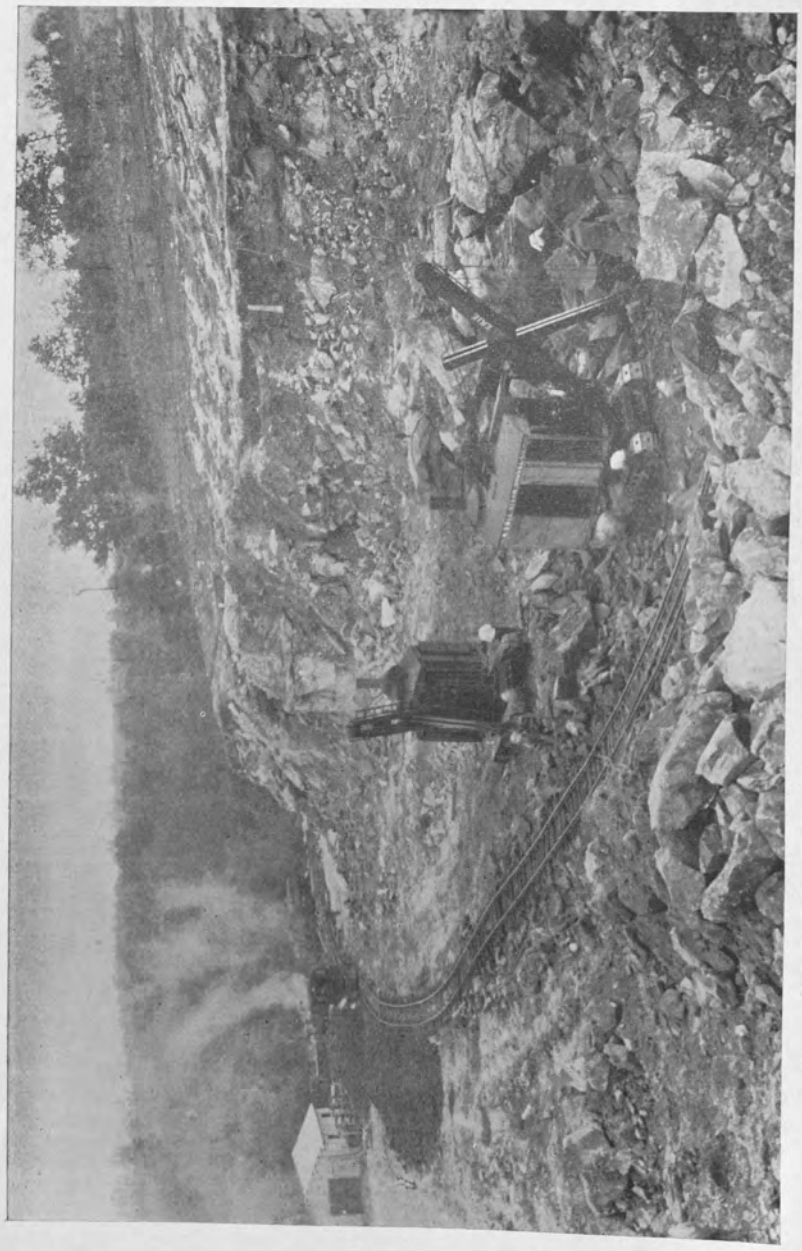
Geology of Edmonson County

1927



ROCK ASPHALT QUARRY ON GREEN RIVER, EDMONSON COUNTY, KENTUCKY

Modern quarry practice is followed in all of the asphalt operations in Kentucky. In this particular district are found some of the best asphalt deposits in the State. Hundreds of millions of tons of crude asphalt rock now in sight in the ground guarantees a gigantic expansion of this industry during the next few years. The topography shown here is quite typical.

The GEOLOGY *of* EDMONSON COUNTY

A detailed presentation of the physical, stratigraphic, structural, and economic geology of this district with a description of the methods of cavern formation in the Mammoth Cave region

BY

JAMES MARVIN WELLER

ASSISTANT GEOLOGIST

Illustrated with fifty-six photographs, maps, and diagrams including colored geological map published separately

The Kentucky Geological Survey

FRANKFORT, KY.

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Preface

One of the earliest geological features in Kentucky to command world attention was the Mammoth Cave in Edmonson county. Discovered by a bear hunter, as unrefuted tradition has it, this great cavern was probably well known locally prior to Statehood. It has grown in popular interest ever since. Millions have visited its dark and mysterious passages. Others have marveled at the unique "sink hole" topography surrounding. Still others with an eye for the practical as well as the scenic, have visited the cave, crossed the limpid clifted waters of Green river and pushed on to explore the more remote parts of Edmonson county. Here great areas of asphalt rock have been found, particularly on the waters of the crooked Nolin river and Bear Creek. Other important minerals have also been noted.

As the years have passed little has been done, however, to set out in an accurate way the detailed geology and resources of this important and interesting region. With the recent completion of the topographic base map of Edmonson county, the way was opened for a careful field investigation. Dr. J. M. Weller, with several able assistants, was selected to do the work. Many difficulties were encountered as the work progressed but these were effectively met. As a sequel, this report, written so as to be understandable to the layman as well as the geologist or engineer, is presented to the public. It is felt that this treatment will add much to the detailed literature of this part of Kentucky, destined by public opinion to become in part at least a unit in the "National Park" system. It is hoped that the stratigraphical, structural and economic geology here presented, as well as the detailed geological map published separately, will assist materially in advancing the development of the mineral and natural resources of this largely virgin field and the Commonwealth of which it is a part.

W. R. Jillson

Director and State Geologist.

Old Capitol
Frankfort,
Dec. 1, 1927.

Letter of Transmission

DR. W. R. JILLSON,
Director and State Geologist,
The Kentucky Geological Survey,
Frankfort, Ky.

Dear Sir:

I enclose herewith my report on the Geology of Edmonson County to appear as volume twenty-eight of the present series of Kentucky Geological Survey publications.

Edmonson County is of outstanding interest both on account of its rock asphalt deposits and its caves. Much money is at the present time invested in the rock asphalt properties and plants and plans are now under way for considerable additional development in this industry.

Mammoth Cave, which is without doubt the most famous cavern in the world, is only one of the caves within the county which are visited by many thousands of tourists every year. The popular interest for which these caves are responsible will probably result in a wider circulation of this report among laymen than is usually the case with geological literature. For this reason I have attempted to use as few technical terms the meanings of which are not generally understood as possible and when it has been necessary to use them to avoid the frequent repetition of certain equivalent phrases their meanings have been explained. I have also included in this report for the benefit of the lay reader explanations of certain geological processes which might otherwise be considered superfluous.

Respectfully submitted,

J. MARVIN WELLER, PH. D.

The University of Chicago,
Chicago, Ill.,
August 1st, 1925.

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GEOLOGY *of* EDMONSON COUNTY

CHAPTER 1

INTRODUCTION

Location and Extent

Edmonson County is located in the west central part of Kentucky, Brownsville, its county seat, being 80 miles south-southwest of Louisville and 22 miles north-northeast of Bowling Green. The county includes an area of 318 square miles. it is very irregular in outline and is bounded by Grayson County on the north, Hart County on the northeast, Barren County on the southeast, Warren County on the south and southwest and by Butler County on the west. Edmonson County lies partly within each of the Leitchfield, Cub Run, Brownsville and Mammoth Cave quadrangles of the United States Geological Survey's Topographic Atlas. The southern part of the county is a part of the Kentucky "Pennyroyal," while the northern part is embraced within the Western Coal Field.

Importance

Edmonson enjoys economic importance over the adjoining counties in only one respect. This importance is based upon its great resources of natural rock asphalt which occurs at

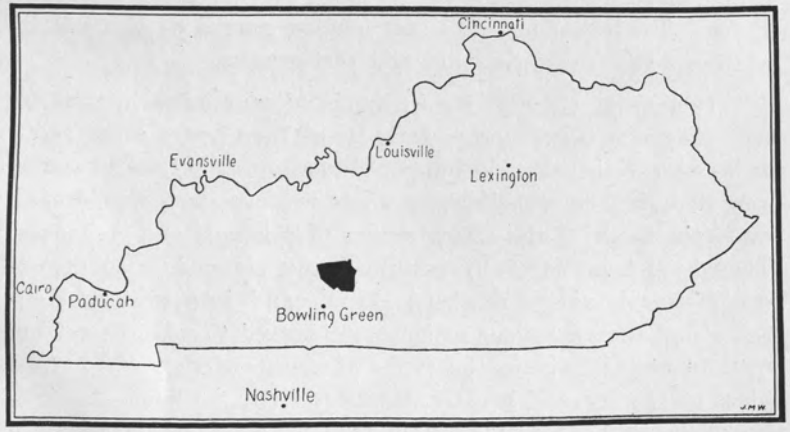

FIG. 1. MAP OF KENTUCKY SHOWING LOCATION OF EDMONSON COUNTY.

many localities in the lower Pennsylvanian beds along Green and Nolin Rivers and Bear Creek. This material is being produced from three large quarries, one upon the north side of Gulf Hollow, a second on the waters of Honey Creek, and a third upon the west side of Nolin River three and one-quarter miles above its mouth. This rock asphalt is shipped to all parts of the United States and abroad. It is chiefly used in the surfacing of city streets and country highways.

Aside from its rock asphalt, Edmonson County possesses other rocks and minerals which although not at present exploited may become important in the future. These include oolitic limestone similar to that which is extensively quarried in the neighborhood of Bowling Green and various types of clays. A small amount of petroleum is being obtained from the southwestern part of the county and producers are optimistic concerning the possible extension of the Bowling Green field within this area. Small amounts of coal are mined for local use in the northwestern portion of the county and iron was formerly smelted in the vicinity of Nolin River.

Edmonson County is best known, however, for its caves, and thousands of tourists visit it every year. Among these Mammoth Cave, which has long been considered by many to be one of the natural wonders of the world, is of chief interest. The beauty of the caves, however, does not surpass the rugged grandeur of the hills and valleys upon the north side of Green River. The towering cliffs and narrow gorges of this region are decidedly romantic, wild and picturesque.

Edmonson County, Kentucky, is of particular interest to geologists as it is the most easterly tip of the Chester embayment in Western Kentucky. The upper Mississippian beds of this area were deposited in a shallow sea whose western shore was located upon the flank of the Ozark region of Missouri and Arkansas. They have been carefully examined and mapped in southeastern Missouri, across southern Illinois and into western Kentucky and the variations which are observed to take place from west to east illustrate the types of sedimentation which take place at greater and greater distances from the land.

This part of Kentucky is also of considerable scientific interest from a physiographic standpoint. The physiographer

will note on the topographical map numerous features such as the deep sinuous valley of Green River, the flat topped hills, the large and numerous sink holes and many more which are all indicative of the processes which have been active during the period of time that has elapsed since this area was lifted above the sea, and which record the recent history, in a geologic sense, through which this region has passed. Edmonson County's famous caves and the features which may be observed within them are also of a highly significant character to the physiographer who attempts to reconstruct the stages through which this part of Kentucky has passed during the evolution of the land surface.

Field Work

The field work upon which the Mississippian portion of this report is based was conducted during the months of August and September, 1924; A. J. Culbertson and H. D. Crider acting as efficient field assistants. Mr. Culbertson left the first of September while Mr. Crider aided throughout the whole season. This part of the survey was made under the personal supervision of Dr. Stuart Weller, who also cooperated in the field work during September. Headquarters were established at Brownsville, from which point it was possible to reach most portions of the county by automobile.

A thorough familiarity with the section involved was obtained during the latter part of June and July in the adjoining portion of Warren County. This alone made it possible to cover the whole of Edmonson County within the space of two months. The routine work was necessarily of a slow and tedious nature due to the relief and greatly dissected character of the country and difficulties which were encountered in getting from place to place. It was impossible in this short time to examine all outcrops and make extended inquiries of the inhabitants concerning the various geologic features. The work consisted mainly in the making of detailed sections at closely spaced localities where it was considered that the best exposures were to be observed. These sections were made by means of aneroid barometers and the results, largely the contacts between the various formations, recorded directly upon the field maps. In the neigh-

borhood of faults and other irregularities the country was carefully searched for all available information but in the more regular portions of the county the information obtained along the lines of traverse was projected across the small intervening areas.

During the months of July, August and September, 1924, Dr. T. F. Jackson conducted an investigation of the Pennsylvanian beds of Edmonson County. He is responsible for determining the locations of isolated occurrences of Mississippian beds outcropping in the valley of Bear Creek and its tributaries, as only those reported by him were visited and examined by the writer and his party.

The latter part of June and the early part of July, 1925, were employed by the writer, assisted by Dr. A. H. Sutton, in reviewing the Pennsylvanian geology of the county and in supplementing to some extent the observations of Dr. Jackson, which have been freely used in the preparation of this work. The locations and extent of the rock asphalt outcrops shown upon the geological map of the county are to a large extent the work of Dr. Jackson, to whom much credit is due for a painstaking piece of work in an area which because of a variable stratigraphy presents many real obstacles in the field.

Topographic Maps

The Brownsville, Mammoth Cave, Leitchfield and Cub Run quadrangles of the United States Geological Survey's Topographic Atlas were used as the base maps for the examination of Edmonson County. These maps are constructed on the scale of 1:62,500 (one mile to one inch approximately) and the topography is shown by 20 foot contours. The Brownsville sheet was surveyed in 1919 and 1921, the Mammoth Cave in 1921 and 1922, the Leitchfield in 1922 and the Cub Run in 1922, 1923 and 1924. The topography of the last two quadrangles is for the most part fairly good considering the roughness of the country and the large proportion of the area covered by woods and brush. The northern portions of the Brownsville and Mammoth Cave sheets, however, do not equal in standard the other two sheets.

Acknowledgments

The writer is chiefly indebted to Dr. Stuart Weller for aid and helpful suggestions during the prosecution of the field work and for criticism of this manuscript. He has also contributed to this report by the collection and identification of the fossils the list of which are included in Chapter VI, and the remarks concerning the paleontology of the various formations are largely based upon his authority.

Acknowledgments are due to J. A. Culbertson, H. D. Crider and Dr. A. H. Sutton for their interested and enthusiastic cooperation in the field. Officials of the Louisville Gas and Electric Company have kindly furnished surveys of some of the caves, which were recently made by them in connecton with the proposed erection of a power dam near Mammoth Cave. The cave photographs included in this report are reproduced by the permission of L. P. Edwards of Great Onyx Cave and George Yarrell of Glasgow Junction by whom they are copyrighted. The survey of Mammoth Cave, which is shown on Plate 2, is reproduced by permission of the Standard Printing Company of Louisville. Local officials of the various rock asphalt companies as well as Judge M. M. Logan, of Bowling Green, and Mr. J. C. Van Meter, of Bee Spring, contributed much information concerning the nature and extent of the rock asphalt deposits and the development of the industry in the district.

Many of the inhabitants of Edmonson County are to be thanked for contributing information concerning the occurrence of outcrops of the various formations and other matters of interest. Finally, Dr. W. R. Jillson, Director of the Kentucky Geological Survey, has contributed in various ways to the successful completion of this examination.

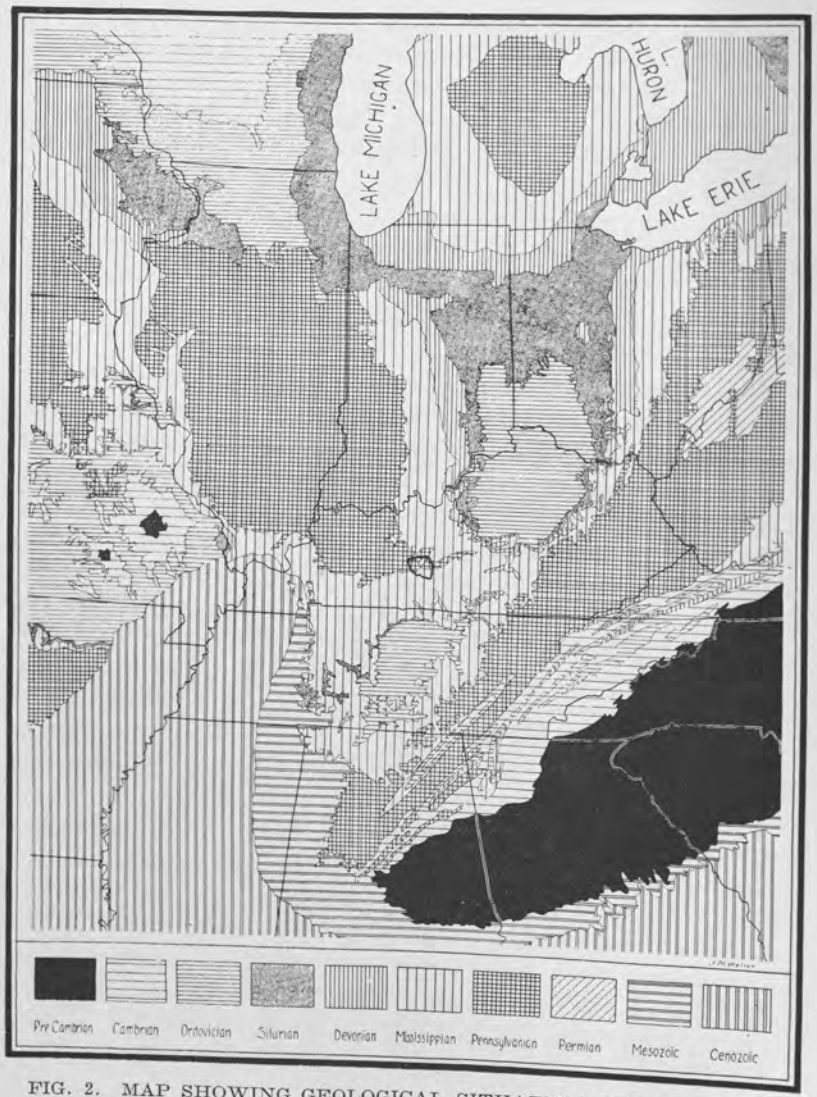

FIG. 2. MAP SHOWING GEOLOGICAL SITUATION OF EDMONSON COUNTY.

CHAPTER II.

GEOLOGIC RELATIONSHIPS

Physiographic Relationships.

Edmonson County lies upon the border between the western Kentucky coal basin and a division of the Pennyroyal known as the "Barrens." It was so called by the early settlers on account of its treeless condition. The northwestern portion of the county is included within the coal basin while the extreme southeastern corner projects into the "Barrens." The intermediate area, which includes the major portion of the county, lies within the transitional zone and is characterized by rugged topography of considerable relief produced by the dissection of an ancient plateau, remnants of whose surface are to be recognized in the flat tops of many of the hills and ridges.

Stratigraphic Relations.

The geological formations which are exposed within Edmonson County are all of Carboniferous age and range from the St. Louis Limestone to the Pottsville. The St. Louis, which is the oldest formation, outcrops in the extreme southeastern corner of the county, is overlapped in the northwesterly direction by younger and younger beds until, in the northwestern portion of the county, the Mississippian strata are completely buried beneath the Pennsylvanian. The Mississippian formations of Edmonson County are continuous with exposures which extend westward along the southern border of the coal field to Crittenden and Livingston counties and thence completely across southern Illinois. To the north they are continuous with the exposures in Breckenridge County which extend northward into southwestern Indiana. The Pennsylvanian strata of Edmonson County constitute the southeastern tip of the great coal field which underlies the greater part of Illnois, the southwestern portion of Indiana and a considerable area in western Kentucky.

Although no beds older than the St. Louis are exposed within Edmonson County, the formations which make up the lower part of the Mississippian, the Devonian, the Silurian and the Ordivican systems, and which are known to the east and south upon the Cincinnati and Nashville domes, undoubtedly extend beneath this area. It is also probable that the Cambrian, which is known in the Applachian region to the east and the Ozarks to the west, underlies Edmonson County at considerable depth.

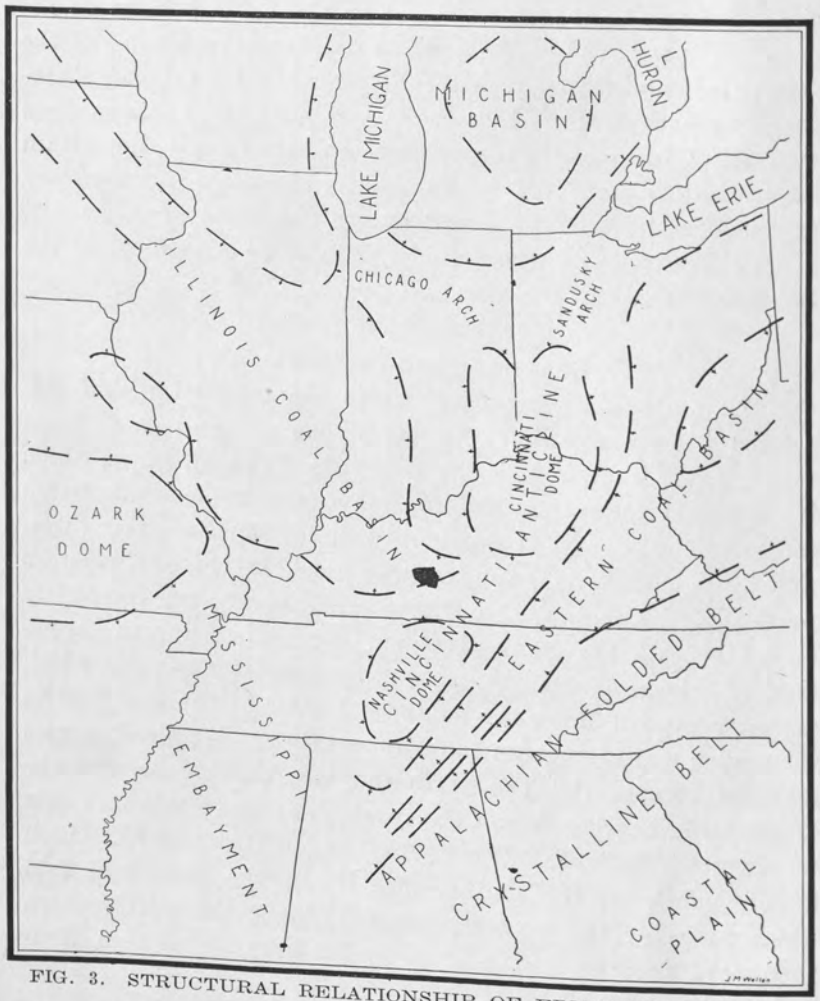

FIG. 3. STRUCTURAL RELATIONSHIP OF EDMONSON COUNTY.

Structural Relationship.

Edmonson County lies upon the western flank of the Cincinnati Arch about midway between the Lexington and Nashville domes. These two conspicuous structures are separated by a saddle which is the easternmost extension of the great synclinal basin which extends to the west and north and contains the coal fields of Illinois, Indiana and western Kentucky. Edmonson County lies just upon the southern side of the axis of this syncline and the beds throughout the county possess a general dip to the northwest of about 30 feet to the mile. This gentle northwest dip is interrupted, however, by numerous local irregularities, notably small faults.

CHAPTER III.

GEOGRAPHY

Introduction.

General Features. Edmonson County is a region of rugged topography and considerable relief. The valleys are deep and are separated by intervening hills or ridges with steep, sometimes precipitous, slopes and comparatively flat summits. The maximum relief developed in the county is 500 feet between the lowest point, about 410 feet above sea level, located at the junction of Bear Creek with Green River at the western border of the county, and the highest points, located upon the divide between the Green and Nolin Rivers where three hill tops rise above the 900 foot contour. While 500 feet is the maximum relief in Edmonson County the local relief is sometimes nearly as great, such being the case on the north side of Green River just west of the mouth of Buffalo Creek, where a single slope rises 460 feet above the river.

On the basis of the various topographic features, Edmonson County may be divided into seven topographic areas as follows:

1. The Southern Sink Hole Plain.
2. The Dripping Spring Escarpment.
3. The Interior Plains.
4. The Valley Sink Area.
5. The Knob Belt.
6. The Hilly Country.
7. The Sunfish Area.

Southern Sink Hole Plain. The Southern Sink Hole Plain occupies the extreme southeastern corner of the county between Glasgow Junction, in Barren County, and Smith's Grove, in Warren County. It essentially corresponds to that area which is shown upon the geological map to be underlain by the St. Louis Limestone, but it extends a short distance north of the St. Louis outcrop and includes a narrow east-west belt upon the outcrop of the overlying St. Genevieve Limestone. It is bounded upon the east, south and west by the county line, and

upon the north by the Dripping Spring Escarpment and the Valley Sink Area. The Southern Sink Hole Plain varies in elevation between 540 and 730 feet above sea level. Its lowest elevations occur in the bottoms of several of the sink holes, its

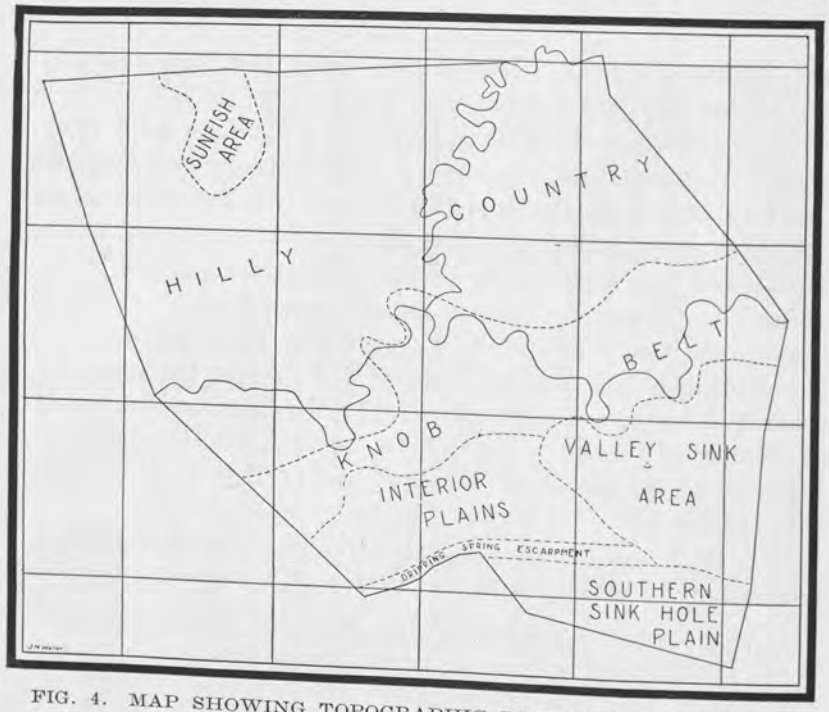

FIG. 4. MAP SHOWING TOPOGRAPHIC DIVISIONS OF EDMONSON COUNTY.

highest point being in the extreme southeastern corner of the county. The average elevation of this area is about 620 feet. The land surface exhibits a prevalent northward slope converging from the east and west toward the lowest part of the area two and one-half miles northeast of Rocky Hill.

This plain is characterized by the exceedingly numerous sink holes which pit its surface. The uplands of the area slope gently, as has been indicated above, but the sides of many of the sink holes and particularly the smaller ones are abrupt, so that the detailed features of the plain are notably uneven. The sink holes are mostly small, though in places a number of them

may combine to form larger sink-like depressions. Gardner Creek and a much smaller branch a little more than a mile to the east are the only surface streams in the area and these empty into sink holes and their waters are carried off under ground. The outlets of many of the sink holes have become clogged, causing the accumulation of the surface waters in ponds, but with the exception of the water which collects in this manner, the rainfall drains off quickly and is carried away through subterranean channels.

The absence throughout this area of streams capable of erosion is responsible for the thick accumulations of residual clay which effectually masks the underlying limestone over most of the surface. The greater portion of this plain is under cultivation and forms the most productive agricultural district of Edmonson County.

Dripping Spring Escarpment. The Dripping Spring Escarpment[1] is the most conspicuous topographic feature of southern Edmonson County. It is developed as a continuous ridge extending in an east-west direction from a point two miles west of Boiling Spring School in northeastern Warren County to a point two and one-half miles southeast of Liberty. It is a little more than 13 miles in length and rises from 160 to 240 feet above the lower land south of it. This escarpment forms the southern boundary of the county for a distance of four miles and separates the Southern Sink Hole Plain from the Interior Plains. In the vicinity of the east line of the county rises a group of hills whose summits and southern slopes correspond to the eastern extension of this escarpment. In this part of the county, the continuity of the ridge has been broken by a number of deep, steep-sided valleys, which drain into sink holes located at various points along their bottoms, and the presence of these features is the reason for including this eastern extension of the Dripping Spring Escarpment in the Valley Sink Area, with which it is topographically continuous.

The Dripping Spring Escarpment faces to the south, and this southern slope is from two to four times as steep as the more gentle slope which descends to the north. The surface of

[1] Willard Rouse Jillson, "American Karst Country," Pan. Amer. Geologist, Vol. 42, 1924.

the northern slope dips away at the rate of from 100 to 175 feet in a mile while the steep southward facing escarpment is seldom more than one quarter of a mile in breadth. The escarpment stands as a remarkably regular, slightly curving line, which is broken only by the notches produced by small northward heading hollows. No spurs worthy of the name project from it to the southward. The ridge, which is bounded on the south by this scarp, gradually increases from an elevation of 700 feet at its western extremity to 840 feet at the eastern end. Its crest in the western part is broken only by low saddles 20 to 40 feet below its general level, but the eastern portion has been divided into a series of more distinctly isolated hills by a number of small northward heading hollows. The most conspicuous of these notches is Chicken Hollow, which has been cut 120 feet below the crest of the ridge. Advantage has been taken of these "passes" for the location of wagon roads and at several such points the public highways cross this otherwise rather formidable barrier.

Interior Plains. Lying north of the Dripping Spring Escarpment are the Interior Plains. As the name implies this area is one of broad gentle slopes which are in strong contrast with the rugged country which surrounds it upon all sides. The area is drained by Beaverdam, Alexander, and the headwaters of Little Beaverdam Creeks. These streams are conspicuously intrenched beneath the plains, and where they pass out of this area their beds lie about 100 feet below the general surface level. With the exception of these steep walled valleys this portion of the county appears to the eye to be almost horizontal but the topographic map shows that a relief of 220 feet actually exists, although the slope of the surface is rarely more than 40 feet to the mile. The highest portion of the Interior Plains lies in the vicinity of Liberty and attains an elevation of 770 feet, from which there is a general slope to the northwest and west which is interrupted somewhat by the low divides which separate the basins of the three creeks which drain this area.

The drainage of the Interior Plains is by no means perfect. East of Alexander Creek small sink holes are numerous, into which much of the rainfall finds its way and is carried off underground. In the area intervening between Alexander and Little Beaverdam Creeks a number of small marshes are present.

Valley Sink Area. In the eastern part of the county north of the Southern Sink Hole Area, east of the Interior Plains and south of Green River, lies the Valley Sink Area which is characterized by a most unusual type of topography. It is a karst area with no permanent surface streams and few springs. The drainage is concentrated from a series of flat ridges into numerous irregular and deep sink holes which are arranged in unmistakably dendritic valley patterns. These valley sinks are steeply incised to a depth of as much as 250 feet below the general level of the intervening ridges. Most of them belong to three systems, each of which possesses outlines essentially similar in all respects to those of normally developed drainage basins. The various branches converge and unite toward Green River just as would the tributaries of an ordinary stream valley.

The walls of the valley sinks are steep and in places precipitous. Their bottoms are commonly uneven due to the presence of numerous small sink holes, although in places, large fairly level tracts do occur. Most of the sink holes along these valleys are freely drained and ponds are not common. The soil is usually thin and rounded hummocks of limestone project through it in many places. In general, there is a decrease in the elevations of the valley bottoms in the direction of Green River, but this is interrupted at many places by reef-like barriers which rise above the general level of the bottoms and connect with the ridges upon both sides. The most conspicuous of these rock barriers are, one which is occupied by the road at Cedar Sink, and another which is traversed by the railroad between Mammoth Cave and Sloans Crossing.

The ridges which intervene between the valley sinks are for the most part flat topped, and decrease gradually in elevation in a northwestward direction. The greatest elevation is attained near Union City at nearly 900 feet above sea level, which decreases to 700 feet towards Green River north and west of Elko.

Knob Belt. The Knob Belt extends completely across Edmonson County diagonally in a northeast-southwest direction. It is bounded on the southeast by the Interior Plains and the

Valley Sink Area, and upon the northwest by the Hilly Country. The eastern two-thirds of the course of the Green River within the county is included in this belt. While the knobs occupy a zone which extends completely across Edmonson County, a dis-

FIG. 5. SOUTHWESTERN SLOPE OF INDIAN HILL.
This is one of the many knobs which occur in the vicinity of Brownsville. The bluffs are formed by the basal sandstone member of the Pottsville. The Leitchfield Formation underlies the grassy slope and the Glen Dean Limestone outcrops in the foreground.

tance of more than 17 miles, their lateral extension is irregular and this belt varies from one to six miles in width, three miles being the measure of its more usual development. The narrowest portion of the Knob Belt occurs along the course of Alexander Creek, the constriction here being caused by the projection of a tongue of the Interior Plains down the valley of this stream. The widest portion of the belt lies between Beaverdam Creek and the junction of Nolin River with Green River.

The topography of the Knob Belt is characterized by rather broad gentle slopes, above which rise in sharp contrast a great variety of steep, sometimes precipitously sided hills. These hills rise from 50 to 200 feet above the gentle slopes and are of two general types, either long narrow ridges with sharp crests, or cone-like peaks, several of which are usually grouped together.

The broad gentle slopes above which the knobs rise are essentially similar to the Interior Plains and are in fact a continuation of them. These plains in the Knob Belt, however, carry

the drainage and in consequence are considerably dissected. This is particularly true in the vicinity of Green River, where the surface slopes steeply to the valley bottom 250 to 300 feet below. On the north side of Green River tributary hollows so cut up these gently sloping surfaces that their continuation in this direction might be overlooked, but once notice is taken of the topography in the region about Cade their continuation is apparent.

Hilly Country. The Hilly Country comprises about one half the total area of Edmonson County. It includes all of the area in the northern and northwestern parts of the county with the exception of about 15 square miles along Sunfish Creek. The Hilly Country is an area of high relief and includes within it both the highest and lowest points within the county. It is composed of alternating high, rather narrow and flat topped ridges, and deep, steep, sometimes precipitously sided V-shaped valleys. A few knobs rise above the ridges, but in general such features are not conspicuous. The valley bottoms are narrow and bottom flats are rarely present except along Reedy Creek in the extreme northwestern corner of the county.

Sunfish Area. A small area in the neighborhood of Sunfish is in strong contrast with the Hilly Country which surrounds it upon the east, south and west. This area is included between Bear and Sunfish Creeks, although it extends to the westward about Hickory Grove and Sunny Point Schools. It is an area of gentle slopes with a prevailing southerly dip of the surface below which the streams are somewhat steeply intrenched. A few knobs rise above the gentle slopes, the most conspicuous of which is Little Mountain.

Drainage

Green River flows completely across the central part of Edmonson County in a direction from east to west and roughly divides it into two nearly equal parts. The northern half of the county is again divided approximately into thirds by Nolin River, which joins Green River in almost the exact center of the county, and Bear Creek whose junction with Green River occurs at the west county line. These two streams are important tributaries of Green River and rise to the northeast far outside of the

county. Only three streams of any size join Green River from the south. They are Beaverdam, Alexander and Little Beaverdam Creeks. They all rise within the county, the largest having a maximum length from head to mouth of about 11 miles, and are of relatively much less importance than either of the northern tributaries of Green River, which have been mentioned. Green River, with these branches and their systems of smaller tributary hollows, carries off all the surface drainage of Edmonson County, although a considerable area, equal to nearly one eighth of the whole county, is drained subterraneously. This karst region lies in the extreme southeastern corner of the county and includes the whole of the Southern Sink Hole Plain and the Valley Sink Area, as well as the eastern and southern parts of the Dripping Spring Escarpment. The only surface stream of any importance within this area is Gardner Creek which flows into a sink one-half mile west of Sinking Spring School. Within this area there are no streams even after heavy rains, flowing directly into Green River or any of its tributaries and the whole rainfall promptly finds its way into subterranean channels.

Being dominantly a region of steep slopes, Edmonson County is well and quickly drained, the only few exceptions being a few small areas located upon the Interior Plains.

Culture

Settlements. Brownsville, with a population of about 250, is the seat of Edmonson County. It is situated upon the south side of Green River, nearly in the center of the county. The only other town within this area is Rocky Hill, located about 11½ miles southeast of Brownsville just north of the county line, with a population about equal to that of the county seat. Country stores, a number of which are also post offices, are scattered over the county at 18 or 20 different localities.

Bowling Green, with a population of nearly 10,000, is the most important city in this part of Kentucky and is situated in Warren County 16½ miles southwest of Brownsville, while Glasgow Junction, which is larger than Brownsville and Rocky Hill combined, is located in Barren County just one mile east of the Edmonson County line.

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There are country hotels at both Brownsville and Rocky Hill and hotels for the accommodation of tourists are located at Mammoth Cave, New Entrance to Mammoth Cave and Great Onyx Cave.

Roads. The main Louisville-Nashville Pike, known as the Dixie Highway, high type surface of rock asphalt in part, crosses the southeastern corner of Edmonson County. Within Edmonson County the Dixie Highway has been surfaced and oiled recently, and is an excellent thoroughfare in every respect. A pike connects the Dixie Highway with Brownsville and extends beyond Green River to the top of the hill one and one half miles to the northwest. Although narrow, this road is in fairly good condition. A pike also connects Mammoth Cave with Cave City, which is situated upon the Dixie Highway 11 miles from Mammoth Cave and about six miles northeast of Glasgow Junction. These are Edmonson County's only hard roads, all others being ordinary dirt roads, which are indifferently worked for the most part. In this region the main roads follow the ridges and only descend into the valleys where absolutely necessary. Almost every ridge of any extent has its road and most of these, while rough, are passable by automobiles, but the hills are usually bad and some of them are exceedingly rocky, those where limestone strata outcrop generally being the worst.

There are no bridges over Green River, but it may be crossed by ferry at Brownsville and at Houchins Ferry. A number of other ferries are indicated on the map, but they are seldom used and are impassable for automobiles. There is one bridge over Bear Creek on the road between Brownsville and Sunfish.

Starting from Brownsville in dry weather one may arrive by automobile within two or three miles of any point in Edmonson County in an hour and a half.

Railroads. The Louisville and Nashville Railroad crosses the extreme southeastern corner of the county, there being a station at Rocky Hill, which is the shipping point for Brownsville. The Mammoth Cave Railroad, a tourist line with amusingly antiquated rolling stock only, connects Mammoth Cave with Glasgow Junction.

Steamboats. Green River is navigable from its mouth to Mammoth Cave. Excursion packets formerly ran between

Evansville, Indiana, and the cave, but this service has been discontinued recently. The only steamboats using the river at the present time are those of the rock asphalt companies located upon Nolin River and Bear Creek. All materials used by these companies and all of the rock asphalt produced by them must be transported by steamboat and barge. Bowling Green may be reached by boat through Barren River, a tributary of Green River, which is navigable as far as that city.

People.

Most of the native inhabitants of Edmonson County are of pure American stock, their ancestors having immigrated to Kentucky in the early days, mainly from Virginia and North Carolina. At one time a few Swedish families settled in Edmonson County, but they have now been entirely absorbed by the remainder of the population. In the northwestern portion of the county the people are mostly Catholics, but elsewhere they are Protestants and largely of the Baptist denomination. The percentage of negroes in the county is exceedingly small and those present are restricted almost entirely to Brownsville and Rocky Hill.

Most of the inhabitants of the county make a rather meager living. Almost the only actual cash that many of them ever possess is received for their tobacco crops or for their labor in the rock asphalt quarries. Much of the land is unfit for agriculture and the soil of the remainder is generally of poor quality, and little incentive is offered for any concentrated effort and as a result of these conditions the social and educational progress of the people has been greatly retarded. While well kept farm houses are the rule in the southeastern part of the county where the land is at its best for agricultural purposes, most of the people in the hilly country live in small cabins, many of them built of logs, and equipped with few conveniences. These people though cautious with respect to strangers are naturally friendly, hospitable, and accommodating even upon short acquaintance.

Industries.

Agriculture. The great majority of the population of Edmonson County is engaged primarily in agriculture. The best land lies upon the Southern Sink Hole Plain and along the

bottom of the Valley Sinks where the soil has resulted from the decomposition of limestone. This soil is clayey, deep red in color and is said to be deficient in phosphorus. The Interior Plains and the gentle slopes of the Knob belt and the ridges of the Valley Sink Area are next in importance agriculturally. Much of the soil of these areas is somewhat sandy in character and is not so productive as the soil of the lowlands to the south.

The steep slopes of the Hilly Country render much of the land in the northwestern half of the country unfit for agriculture, but the tops of the ridges and the valley bottoms are generally under cultivation, although the soil is inferior. The high relief which prevails throughout most of the county and the resulting rapid runoff of the rainfall makes much of the land susceptible to droughts which in many seasons greatly damage the crops. Altogether the agricultural resources of Edmonson County are mediocre.

The most important market crops of the county are tobacco and corn. In many cases, tobacco is the farmer's "money crop." Besides these, small quantities only of other products are grown, mainly for local consumption. Due to the depredations of the boll weevil in the more southern states, cotton has been introduced into this part of Kentucky recently, as an experiment, and should the growing of this crop prove to be successful it will become of great importance to the Edmonson County farmer.

Little fruit is raised within the county at the present time and most of that which is grown is of inferior quality, but there are many locations on the hill tops and ridges where orchards, properly cared for, should furnish good returns. Strawberry growing has become an important industry in the adjoining portion of Warren County, where similar agricultural conditions prevail, but growing of this fruit has been as yet little undertaken in Edmonson County.

Little stock is raised in the county, although similarly situated communities find this industry profitable. In nearby portions of Kentucky Angora goats are raised extensively upon waste land and there is no reason why goats, sheep and even cattle could not be raised in large numbers upon much of the land in the county which is unfit for cultivation.

Tourist Resort. Thousands of tourists visit the caverns of Edmonson County every year. Over forty thousand people are said to have visited Mammoth Cave in 1923. The New Entrance to Mammoth Cave and Great Onyx Cave also have many visitors in the course of a season. The admission rates to the caves are standard; $2.20 for the first trip and $1.10 for each additional trip. It is estimated that the tourists, during the season of 1923, spent approximately one quarter of a million dollars in Edmonson County for admission to the caves, hotel accommodations, meals, motor supplies and miscellaneous purchases. This figure is imposing but it is of little significance in the economic aspect of the county as a whole because most of it goes to the cave owners who employ comparatively few people and consequently only a small part of this money finds its way into circulation among the inhabitants of the county.

The United States Government has recently made Carlsbad Cave in New Mexico into a national park. This cave has only recently become known to the public and is reported to be somewhat larger than Mammoth Cave, but it can never rival it in historic or general interest. The unrotted timbers which mark the activities of the saltpeter miners during the War of 1812, and the names and dates smoked upon the roofs of some of the corridors appear as fresh as though they were made but yesterday, although they go back to pre-Civil War times. Mammoth Cave is probably the most widely known cave in the world and is accessible to the great majority of the people of the United States. When these facts are considered it seems only proper that this region also should be set aside as a national or state park and preserved for all time as the property of the people.

Rock Asphalt. By far the most promising industry which has yet been developed in Edmonson County is the exploitation of its natural rock asphalt. At the present time three quarries are in operation and furnish employment for about 1,000 or 1,100 men. A fourth will be opened on Nolin River in the near future. The rock asphalt companies have invested much money in land and equipment. The Kentucky Rock Asphalt Company with its quarry located at Kyrock on Nolin River is the largest and oldest of these concerns. Its plant is modern and efficient and is equipped throughout with first class machinery. The same may

be said of the Natural Rock Asphalt Company and the United Rock Asphalt Company. The labor in the asphalt quarries is almost all recruited locally and many of the men live in cabins on small hill farms and go back and forth daily to their work.

The greatest problem which the rock asphalt companies have to deal with is one of transportation. At the present time all of their fuel, supplies and equipment are brought in by steamboat on Green River and the asphalt is shipped out in the same manner. The asphalt which is produced is used mainly for surfacing streets and roads and is of excellent quality. A portion of the Dixie Highway a short distance south of Louisville was built nearly ten years ago with rock asphalt from Edmonson County and it is still in perfect condition. The value of this material has been proved and the demand exceeds the supply. It is probably only a matter of time before a connecting railroad will be built to Brownsville, either from the Louisville and Nashville Railroad to the south, or from the Illinois Central to the north. A railroad is all that the county needs to promote the development of its rock asphalt resources and secure production upon a large scale.

Lumbering. Except when court is in session, Brownsville is a quiet little hamlet, but once, when railroad ties were being cut and shipped out of the county by the thousands, it was a busy and prosperous little town. Almost all of the first class timber has now been cut and the remainder is going rapidly. The only large trees to be found in the county at the present time are in the most inaccessible parts of the hills. A few small saw mills are scattered over the county and are operated intermittantly to fill local demands. Some railroad ties are being cut, every tree large enough to make a single tie is being sacrificed. The demand for such timber is insatiable. The trees are ruthlessly cut and the land allowed to become overrun by second growth. The tragedy is that the trees which spring up spontaneously on cut over land are of different species from those which were formerly dominant and as a rule they are of practically no value, but with proper forestry regulations the timber crop might be made into an asset of prime importance in the country.

Oil. A few producing oil wells are located in the southeastern corner of Edmonson County, but the oil industry is of little importance to the county as a whole. It is possible, however, that pools comparable to those in Warren County may be discovered in the future, in which case Edmonson County would then take its place among the important oil producers of Kentucky.

Coal. A little coal is mined in the northwestern portion of the county but its production is entirely seasonal and satisfies the local demand only. The thinness of the seams, the comparatively low quality of the coal and the absence of rail transportation will prevent this small industry from attaining great importance.

CHAPTER IV.

PHYSIOGRAPHY

Introduction

Physiography is the study of the development of the topographic form of the land. It deals with the agencies which have actively modified the details of the surface, the conditions which have passively influenced the modification, and the processes which have resulted from various combinations of agency and condition. Physiography is descriptive, in that the present form of the land is contrasted with the configuration which it possessed in the past, and it is explanatory in that the reasons for such changes are set forth.

Physiographic Agencies

The present topographic features of Edmonson County are almost entirely the result of erosion. The present streams have been in existence for many thousands of years and their ceaseless activity has dissected a nearly level plain into the rugged country as seen today. One portion of the water which falls as rain sinks into the soil, another portion is carried away by the streams, and this division of waters accounts for the two physiographic agencies which have been responsible for the topographic development of Edmonson County. The erosive action of water in a region such as this is two fold, first corrasion, or the mechanical wearing away of the rocks, and second solution. Running water in streams, which is responsible for the development of hills and valleys, is largely an agent of corrasion, solution playing a minor role. Sand and gravel carried along in suspension by the streams act as abrasives, wearing down the rock over which they pass. The speed with which corrasion is accomplished depends mainly upon two factors; first, the rate at which the stream flows, and second, the amount of cutting material which it carries.

The rate of flow of the stream is in turn dependent upon two factors; first, its gradient, or the steepness of its descent, and second, its volume, or the amount of water which it carries. Dur

ing flood stages when its volume is greatest, a stream flows much more swiftly than it does at low water, and is able to move greater amounts of coarse sand and gravel. These sediments, carried by the stream, are the tools by means of which the rock of its bed is worn away. Obviously, clear water flowing over bare rock has little erosive action. A heavy load of sediment, on the other hand, reduces the velocity of a stream and in consequence there is a tedency for part of the sediment to be deposited in the channel, thus protecting the rock to some extent from the corrasive action of the stream. A moderate amount of sediment is, therefore, most efficient for stream erosion.

The erosive activity of ground water, or that portion which sinks into the soil, is in strong contrast to that of running water. As has been shown, running water is most largely a corrasive agent, but ground water is active chiefly as an agent of solution. The movement of ground water through the pores and crevices of the rock is exceedingly slow, but it is in intimate contact with the rock for considerable periods of time and has the opportunity for solution which running water does not have. Just as running water erodes in some places and deposits sediment in others, so ground water in some places dissolves and elsewhere deposits its material from solution. However, solution greatly exceeds deposition and ground water tends to make the rock through which it passes more porous. The effect of the solvent action of the ground water upon the various types of rock differs greatly. In sandstone the tendency is toward the solution of the cementing material and this type of rock is commonly left in a weakened state, the sand grains being less firmly bound together so that the rock crumbles and is more easily eroded by running water. Shale is practically impervious to ground water and little or no change is produced in beds of this type.

In the case of limestone, however, the action of the ground water is of the greatest importance. Limestone which is slightly soluble is in some cases made more porous, but in others certain portions of the rock are dissolved entirely and sinkholes, caves and underground channels are produced. Many underground streams flow in channels dissolved in the limestone, and in these the ground water moves with the velocity which is common to many surface streams, and not only solution, but corrasion as

well, may take place. The potential possibilities of underground streams as erosional agents, however, are realized in but few cases, for the sediment which is necessary to furnish sharp cutting material is generally absent. Most underground streams are perfectly clear under ordinary conditions, although some, having more open inlets from the surface, do carry much sediment after heavy rains, a fact which is shown by some springs becoming muddy at such times.

Factors Affecting Physiographic Development

The type of topography produced in a region by erosion upon a raised plain or plateau depends upon a number of factors. The most important of these are altitude above the sea, stratigraphy, structure, position of drainage courses and climate.

The altitude above the sea of a given region determines the degree of relief which may be developed. Erosion given sufficient time, is capable of reducing a land surface of large extent to a plain but slightly above sea level.

Stratigraphy refers to the character and sequence of stratified rocks which are present. Some rocks are much more easily eroded than others. Shale, for example, is rapidly cut away by the streams; limestone and sandstone are much more resistant.

Topography developed upon a homogeneous series of strata is normally characterized by rather uniform slopes from valley to hilltop, but if different types of rock are interbedded, the hills may rise by a number of terraces, each of which is developed upon a resistant bed.

Earth movements taking place subsequent to the deposition of the rock modify their original nearly horizontal position and cause the beds to dip in some one or more directions. Topography produced by the erosion of steeply dipping beds is characterized by long, narrow and parallel ridges and valleys. Such valleys are cut along the outcrops of the weaker strata, while the more resistant beds produce the ridges. In a region of gently dipping beds the valleys possess no definite arrangement, but the hills in many cases possess a much steeper slope upon the up dip side, due to the greater opportunity for the undermining of the resistant strata upon this side. The crests of the

ridges in a region of gentle dips may slope gently in the same direction as the beds.

The position of the major drainage courses upon the surface of an uplifted plain may have been the result of certain conditions which are no longer apparent after this plain has been dissected. The positions of the large streams at the time when they began to cut deeper into their valleys is highly important, however, for in most cases they will continue to follow the same courses as long as erosion continues. The main streams control the drainage of an area which converges toward them and under normal conditions a general regional slope toward their valleys will be produced.

Climate. Rainfall is the chief climatic factor which influences physiographic development. The rainfall in its amount and seasonal distribution largely determines the type of vegetation which will flourish in a region. Abundant vegetation is acknowledged an important factor in the retardation of erosion.

Limestone is somewhat soluble in natural waters and in other than arid regions this rock is removed in solution, to a large extent, for this reason. In regions of moderate, or heavy rainfall, limestone is less resistant to erosion than sandstone and consequently the sandstones cap the hilltops while the limestones are reduced to lower elevation and in some cases are pitted with sink holes and honeycombed with caves.

Cycles of Erosion

General Remarks. Erosion tends to reduce a land surface to base-level. Sea level is the ultimate base-level, but the elevation at the mouth of the river which drains it is the base-level for any given region. If a region remains undisturbed, erosion will continue until the land has been reduced to a nearly level surface sloping so gently that running water can no longer effect the transportation of material. Such a surface is termed a *peneplain.* If the land surface is uplifted or if the controlling local base-level is reduced, the streams are again enabled to transport sediment. They entrench themselves in the old valleys and are said to be rejuvenated. The time which elapses between one rejuvenation and the next is termed a cycle of erosion and such a cycle is the unit of physiographic development.

In Edmonson County there are three different types of features, which serve as a criterion for the recognition of ancient base-levels. These are high level flats, hanging and abandoned valleys and cave levels.

High Level Flats. If peneplaination of a region is not carried to completion before the uplift which initiates a new cycle of erosion occurs, certain hills or erosion remnants remain, rising above the peneplain surface. A succession of several stages of partial peneplaination, each less complete than the one before, may in this way leave hills and ridges between the main valleys which rise by a series of terraces. In nature, however, such terraces are usually indistinct and in many places entirely wanting, as with each rejuvenation the flats developed by each preceding period of peneplaination are attacked by erosion and gradually tend to be obliterated. The higher peneplain levels, on account of their having been subjected to erosion for longer periods of time, are less distinct than the lower and more recent ones. Should any stage of peneplaination be of longer duration or of more extensive development than one or more of those which preceded it, all evidence of these former stages may be destroyed and the topographic configuration will give no hint of these erosion cycles.

The stratigraphy of any region plays a highly important role, both in regard to the extent to which the process of peneplaination may progress in any given interval of time and the perfection with which ancient peneplain levels are preserved upon the hills. Peneplaination will, of course, take place more rapidly in a region where the strata are easily eroded than in areas where resistant formations are present. A comparison of eastern and western Edmonson County illustrates this point excellently. After rejuvenation, peneplain flats will be preserved for more than short periods of time only in exceptionally favorable localities where erosion is reduced to a minimum, as upon the crests of hills and ridges or where this level surface has been cut upon some formation which is unusually resistant to erosion.

High levels are apparently preserved in Edmonson County and in the surrounding portion of Kentucky at intervals

which are rather uniformly spaced 100 feet above each other. Great care must be observed in the interpretation of these features, however, since certain of them may not represent actual peneplain levels, being simply flat surfaces developed upon

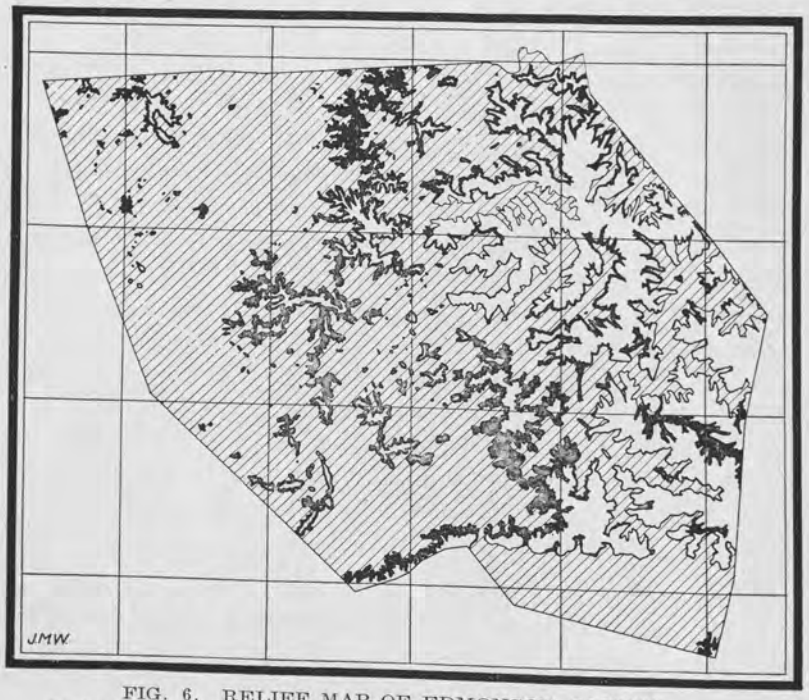

FIG. 6. RELIEF MAP OF EDMONSON COUNTY.
Surface relationships at an elevation of approximately 700 feet are shown. Black areas are about 700 feet, shaded areas are lower, and light areas high.

resistant formations. It is difficult, if not impossible, to certainly distinguish between the remnants of peneplain levels and flat surfaces developed upon resistant formations since the former are most likely to be preserved in those situations where the latter might naturally be expected to occur.

The highest hills in Edmonson County rise a little above 900 feet above sea level and are located along the ridge which forms the divide between Green and Nolin Rivers. In the northwest corner of Barren County a number of hills rise to an elevation of 960 feet, while in the northeast corner of Warren County Pilot Knob attains a similar elevation. These hill tops are, perhaps, remnants which were left standing upon the highest peneplain which can be recognized in Edmonson County, and their crests may perhaps be correlated with the Muldraugh's Hill Peneplain which was extensively developed throughout this region and in many other places both in Kentucky and Tennessee. In Tennessee, the term Highland Rim is used.

An 800 foot level, apparently, is represented by flat topped ridges which extend westward toward Nolin River from the northeastern corner of the county to Bylew Creek and flats present about Straw and along the ridge extending toward Hester School, and also in the vicinity of Cade and Little Jordan School. Similar elevations occur upon several of the ridges which intervene between the valley sinks. A number of the hills in the Knob Belt also rise to the 800 foot level as well as a few hill tops just west of the lower portion of Nolin River. The comparatively wide distribution in the central and eastern parts of the county of flats, standing close to 800 feet, is fairly good evidence of delayed erosion marked by this level.

The existence of a temporary erosional level at an elevation of about 700 feet is certain, flats at this elevation being well preserved about Bee Spring and Pig. Additional evidence is presented by a number of projecting spurs, such as that at Turnhole Bend, and many colls, or low divides between various higher hills, which exist at this elevation. Good examples of these occur separating the several Pottsville capped hills west of Pine Grove School. The 700 foot level is preserved upon a number of hill tops between Big Reedy and Bear Creeks, and remants also remain at many places along Green and Nolin Rivers. The flats developed at the 700 foot level are excellently preserved in Grayson County, northeast and east of Grayson Springs.

Remnants of a level surface developed at the 600 foot level are well preserved along Bear Creek and the western part of Green River in Edmonson County, particularly south and southeast of Little Mountain and south of Huff. As in the case of the 700 feet level, so also at the 600 foot level there are saddles between a number of the higher hills. Such a situation is well shown along the crest of the ridge, about midway between Freemont and Hickory Grove Schools. Flats were developed at this

level to the east along the course of Green and Nolin rivers, and remnants are preserved on three hill tops southwest of Temple Hill Church.

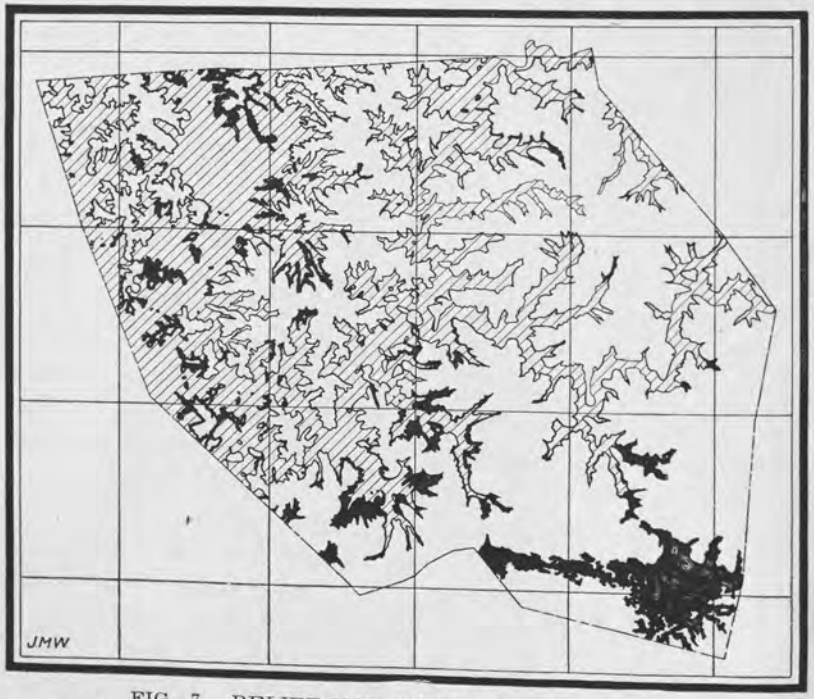

FIG. 7. RELIEF MAP OF EDMONSON COUNTY.
Relationships at an elevation of approximately 600 feet are shown. This elevation is shown in black, lower areas are shaded while higher areas are white.

The existence of a 500 foot level is suggested by the presence of several flat topped hills at this elevation in Butler and Warren Counties just east and south respectively of the junction of Bear Creek with Green River. This level is also to be observed in Edmonson County near St. John's Church and Hickory Grove School.

Hanging and Abandoned Valleys. The gradient of a normal valley is steepest near its head, the slope becoming more and more gentle and approaching the horizontal in a down stream direction. The curve which represents its profile is, therefore, concave upwards. In the southeastern portion of Edmonson County in particular there are a number of valleys which do not

possess this normal gradient. The gradients of these valleys are steep in the headward portions, gentle in their intermediate parts, and steep again near their mouths. Valleys of this type are not in adjustment with the major drainage lines and are known as hanging valleys.

In almost all cases these hanging valleys have also been abandoned as the result of the development of sink holes which carry the waters underground, and at the present time are not occupied by streams. The valley sinks constitute the best examples of this type of valley. Some idea as to the original gradients of these valleys may be obtained by drawing curves connecting the highest points which are now present along their courses. In the case of the valley which separates Mammoth Cave ridge from the Elko-Chaumont ridge such a curve is steep at the head of the valley but flattens out in a short distance to a level of 700 feet and is fairly level throughout most of its extent, but in its lower portion plunges steeply to Green River. It seems to be clear that this valley was once occupied by a stream flowing at the 700 foot level, its waters being captured by subterranean channels shortly after the rejuvenation which followed this period of erosion.

The interpretation of the profiles of the other valley sinks is somewhat less evident, but these valleys are all developed in a nearly uniform series of limestone strata and none of the high spots are due to the presence of resistant beds, being simply remnants of the valley floor as it existed at one time. The transformation of the valley sinks from valleys of the normal types to their present condition probably took place in two or more stages. A few sink holes probably developed more or less simultaneously at various points along the original valley soon after the rejuvenation of the region, thus dividing it into several entirely separate parts. Ordinary erosion reduced these several parts to a greater or less degree. With the advent of a second stage of rejuvenation additional sink holes were developed and the valley became broken up into still smaller parts.

A study of the profiles shown in figure 9 seems to indicate the development formerly of a temporary 700 foot level. Besides

this, it also suggests similarly an 800 foot level, a 750 foot level, a 650 level and a 600 foot level.

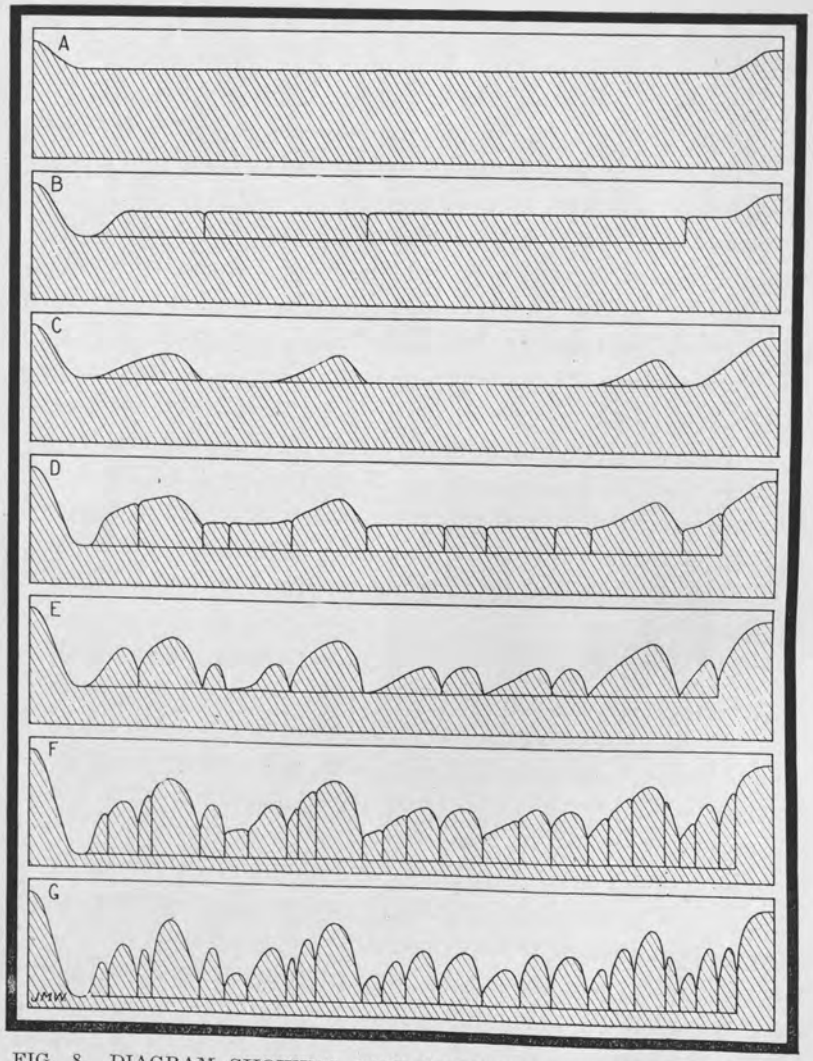

FIG. 8. DIAGRAM SHOWING HOW TOPOGRAPHIC FORMS MAY INDEX THE PHYSIOGRAPHIC HISTORY OF A REGION.

Other smaller hanging valleys along Green River yield further evidence bearing upon the ancient erosional levels. The

sink holes east and southeast of Cade are plainly distributed along the former courses of small streams at an elevation of a

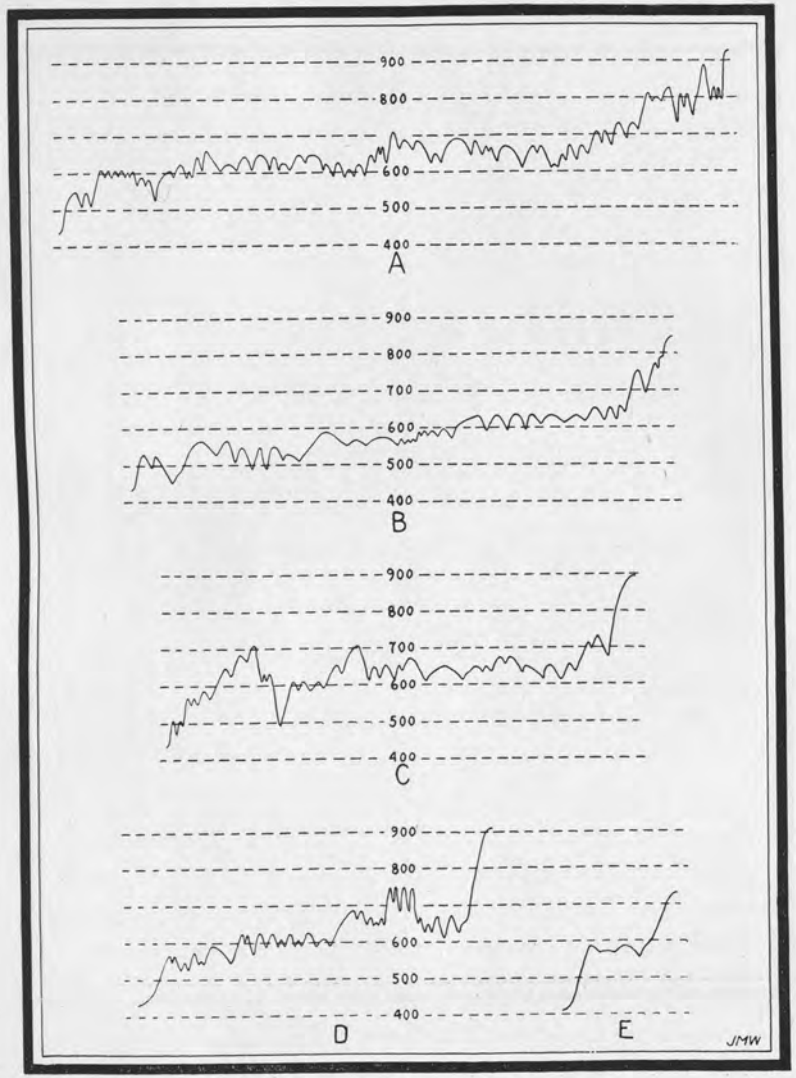

FIG. 9. VALLEY SINK PROFILES.

little over 700 feet. The small valley which joins Green River from the east, just below Beaverdam Creek, known locally as

Cow Hollow, hangs at an elevation just under 600 feet as does also the small hollow east of the Y. M. C. A. Camp near Mammoth Cave. The town of Brownsville is situated in a small valley

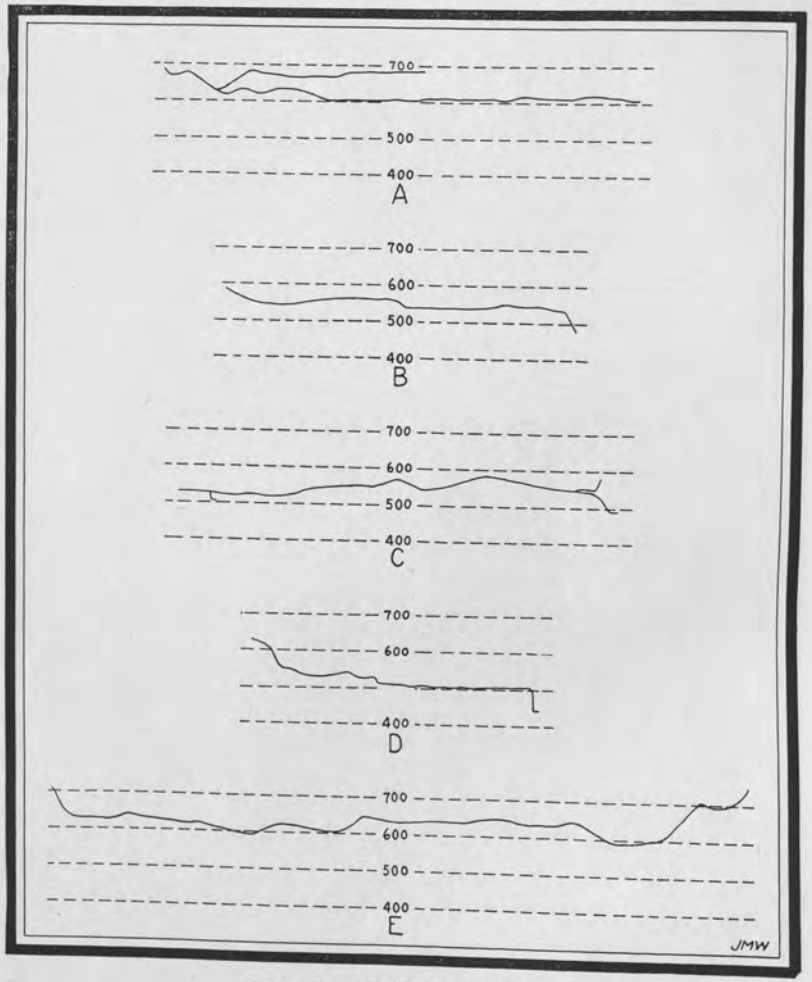

FIG. 10. CAVE PROFILES.

which overhangs Green River at an elevation of about 500 feet. It is also significant that the lowest point upon the rim of the Southern Sink Hole Plain in the southeast corner of the county occurs at an elevation of about 600 feet.

Cave Levels. An inspection of the profiles of certain of the Edmonson County cave passages, which are shown in figure 10, shows the presence of somewhat definite levels at 500, 600 and nearly 700 feet, while other levels are suggested at about 550 and 650 feet.

Absolute reliance cannot be placed upon this underground evidence as it has no bearing upon the case unless the cave passages were formed at base level. Unfortunately, time was not available during the course of the field work for an investigation of this point, nor are any profiles of Mammoth Cave available.

Conclusions. The succession of local erosional level stages as indicated by the high level flats, hanging and abandoned valleys and cave levels has been briefly considered above. None of these lines of evidence is absolutely reliable and as a check the following table, showing the value of the evidence as derived from these three sources, is presented.

Erosional Level About	High Level Plain	Hanging and Abandoned Valleys	Cave Levels
800	Good	Suggested	
750		Suggested	
700	Excellent	Excellent	Good
650		Suggested	Suggested
600	Excellent	Good	Good
550			Suggested
500	Good	Suggested	Good

Drainage Development

Green and Nolin Rivers are both deeply entrenched streams which exhibit many evidences of a downstream migration of their numerous meanders. Several localities which show the results of this action are at Nappers Rollover, Turnhole Bend, between McCoy Landing and the mouth of Buffalo Creek, and at Houchin's Ferry on Green River, and the fish tail meander of Nolin River west of Temple Hill Church. At each of these places, and in fact generally, the sides of the valley which lie upon the concave sides of the bends are much steeper than the opposite slopes. While the effects of downstream movement of meanders are apparent along these Edmonson County streams, the action of this type of stream erosion was not of great importance and these major

streams were probably but little more than just able to keep pace in their downward erosion with the rejuvenation.

Green River Valley. By considering the height of the hills which border Green River some idea may be obtained as to the time at which the course which it now follows was determined.

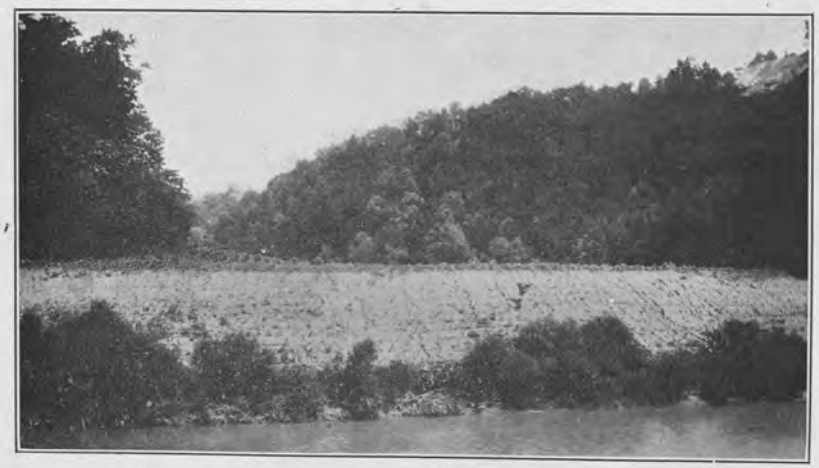

FIG. 11. NOLIN RIVER VALLEY FROM KYROCK.
The view is downstream showing the entrenched character of the valley at this point. The river makes a sharp bend at the right just outside of the picture and flows back upon the other side of the field in the foreground. The bluffs which rise upon both sides are formed by the massive basal sandstone of the Pottsville.

Green River is a synclinal stream. Its head is situated upon the crest of the Cincinnati Arch, between the Cincinnati and Nashville Domes, and it flows westward nearly along the axis of the great syncline which contains the Coal Measures of Western Kentucky, Indiana and Illinois until it joins the Ohio. Without doubt, from the time when the interior of North America was raised above the sea at the close of the Mississippian Period to the present, a river has at various intervals flowed along the same route, although the age of the present Green River cannot be extended back farther than the close of the Paleozoic when the folding which resulted in the greater part of the present structure took place.

The exact course of the river during Mesozoic time is not known as no remnants of the land surface which then existed now remain, but at the time of the period of Cretaceous pene-

plaination, which is recorded by the 800 foot level in Edmonson County, it flowed in the same general course which it follows today since the valley which it occupied at the 700 foot level shows entrenched meanders. From the east county line to the mouth of Buffalo Creek this valley averaged about one mile in width and the river itself was probably in a late mature stage of development, but below the mouth of Buffalo Creek the valley was much wider and the river in this portion of its course was undoubtedly in a state of old age. From the mouth of Buffalo Creek to Pittsburgh Landing, Green River followed a course similar, in a general way, to the one which it now possesses, but the exact location of the stream below Pittsburg Landing is uncertain. During the course of the downward erosion to the 500 foot and present levels, Green River has simply entrenched itself in the course which it occupied at the 600 foot level.

Nolin River Valley. The general course of Nolin River was determined by the position which it occupied upon the 800 foot level. At the close of the period marked by the 700 foot level it had cut a broad valley, averaging two miles in width, from the northeast corner of the county to the mouth of Dismal Creek, below which point its course was considerably restricted. The actual form of the meanders above the mouth of Dismal Creek was probably determined by the course of the stream on the 700 foot level, although from the mouth of this tributary to its junction with Green River the meanders were without doubt inherited from the 800 foot level.

Most of the tributaries of the Green River join the main stream at an angle more or less acute in an upstream direction. This is the normal relation of minor streams in a region of gently dipping strata. Certain of the tributaries, however, enter at an acute angle down stream from the junction. The most notable of these are the hollow which heads between Watts School and Little Beaverdam Creek, Crooked Creek, Honey Creek, the small hollow between Potato and Indian Hills, Buffalo Creek, Blowing Spring Branch and Running Branch, while a number of others exhibit this same characteristic to a less degree. A study of the topographic maps of other parts of Kentucky and Tennessee, in which the major streams are entrenched in well defined mean-

ders, reveals the fact that this relationship between some of the tributaries and the major streams is not uncommon and probably is determined by local stratigraphic factors of control during a very long period of erosion.

FIG. 12. STRAIGHTENING OF A MEANDERING STREAM.
This diagram illustrates the origin of Goblin Knobs in Edmonson County.

Stream Piracy. Stream piracy, or the capture of streams from their original courses by younger channels, has been an important process in the development of the southeastern part of Edmonson County. The most conspicuous cases are those in which the surface drainage has been captured by underground channels, this process having produced the peculiar valley sinks as well as the topography of the Southern Sink Hole Plain. In the case of the valley sinks, the former course of the drainage may plainly be seen by the extent of the valleys which have remained practically intact and, except for the development of the sink holes along their bottoms, have been little altered.

The last stream to drain the Southern Sink Hole Plain in the southeastern corner of the county flowed westward close to the base of the Dripping Spring Escarpment and entered Barren River four miles northwest of Bowling Green through Rays Branch, the waters of this stream being captured by subterranean piracy shortly after the rejuvenation which followed the 600 foot terracing. The course of this stream was established prior to the development of the 700 foot level. At this time its head probably did not extend farther east than Rocky Hill, the most southeasterly corner of the county being drained through Cedar Spring Hollow to Green River. At this time also a considerable portion of the Interior Plains was drained through this extension

of Rays Branch into Barren River, as is plainly shown by the several passes which exist through the Dripping Spring Escarpment at the 700 foot level, of which Chicken Hollow is the most conspicuous.

During the period of down cutting which followed the rejuvenation after the development of the 700 foot level, the

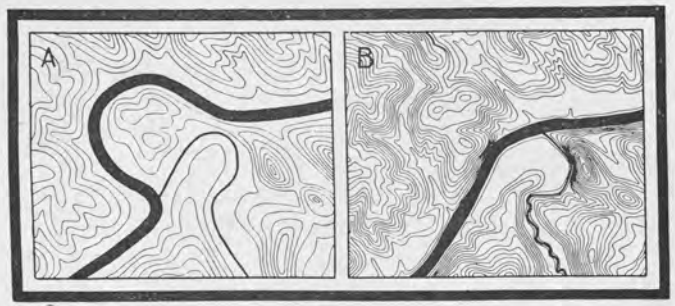

FIG. 13. MODIFICATION IN THE GREEN RIVER VALLEY.
During a previous cycle of erosion the divide separating Green River and Beaver Dam Creek was cut through and the old meander abandoned.

streams which drained northwestward into Green River were rapidly extended headward and captured the drainage of the Interior Plains which had, until this time, passed out to the south and west to Barren River, while Rays Branch, as though to make up for these losses, extended itself headward and captured the drainage of the southeastern corner of the county from Cedar Spring Hollow.

A minor change in the course of Green River was effected at the 600 foot level just west of Brownsville. The river here formerly flowed in a meander up the hollow followed by the Brownsville-Bee Spring Road around the Pottsville capped hill to the southwest and back to its present course, through what is now Limestone Branch. At the same time, Beaver Dam Creek flowed in a meander which impinged against the small steep hill just west of the Brownsville Court House, much as it does today, and thence down the present valley of Green River which it joined at what is now the mouth of Limestone Branch. The narrow neck which separated Beaverdam Creek from Green River just west of Brownsville was attacked upon both sides by the erosion of these streams and was finally worn through and

the river abandoned its old course to flow through the more direct route of the lower portion of Beaverdam Creek.

Brownsville is situated between Pottsville capped knobs in a small valley which hangs at an elevation of about 500 feet. It seems probable that at the 600 foot level the upper part of the hollow which is now a tributary to Beaverdam Creek drained out through this course. With the subsequent rejuvenation, this stream cut down the lower portion of its course to the 500 foot level, but Beaverdam Creek, with greater volume of water, proceeded with the work of deepening its valley much more rapidly and one of its tributaries cut back and captured the upper portion of the stream.

Development of Sink Holes and Caves.

It has long been known that sink holes and caves are produced by the solution of limestone, but the amount of study that these most interesting phenomena have received is almost unbelieveably small. At the present time there is no other branch of physiography which has been so little touched upon or which offers a more fertile and entrancing field for critical investigation. The cave regions of Indiana have received more attention from geologists than any others, but few attempts have been made to work out the principles which govern cave formation[1] and up to the present time no detailed investigation of caves has been presented.

The Western Coal Field of Kentucky is encircled upon the south and east by a wide belt of country some 5,000 square miles in extent which is characterized by sink hole topography. About the eastern extension of the coal field this type of topography is developed to its maximum degree and throughout about 1,200 square miles of this area the drainage is carried almost entirely underground, producing typical karst topography.[2] The Mammoth Cave region which lies nearly in the center of this karst belt is probably one of the most favorably situated areas to be found anywhere in which to study the details of cave develop-

[1] F. C. Greene, "Caves and Cave Formation of the Mitchell Limestone." Ind. Acad. Sci. Proc. 1908, pp. 175 ff.
J. W. Beede, "The Cycle of Subterranean Drainage as Illustrated in the Bloomington, Indiana, Quadrangle." Ind. Acad. Sci. Proc. 1910, pp. 81 ff.

[2] W. R. Jillson, "American Karst Country." Pan-Amer. Geol., Vol. 42 (Aug., 1924).

ment. A portion of this area is mapped on the scale of one inch to one mile. It is easy of access and many of the caves have been carefully explored, among which the best known are Mammoth Cave, Great Onyx Cave, Collossal Cavern, Hidden River Cave,

FIG. 14. INTERIOR OF GREAT ONYX CAVE.

Horse Cave, Crystal Cave, New Entrance to Mammoth Cave, Center Cave,, Dorsey Cave, Salts Cave, White Cave, Dixon Cave, Proctor Cave, Long Avenue Cave, Preston Cave, Highland Cave, Indian Cave, Parker Cave, Doyle Cave, Cave of the Hundred Domes, Mammoth Onyx Cave, Diamond Cave and Cedar Sink Cave.

During the course of the present examination of Edmonson County, insufficient time was available for a study of the caves themselves, and it was possible to visit only Mammoth and Great Onyx Caves, two of the most important of the county. A thorough investigation of the Kentucky caves is at present under consideration by the Kentucky Geological Survey with the intention of learning as much as possible concerning the mode of origin and the principles of development of these interesting features. At the present time little can be added to what is already known concerning the origin of caves, but in order that the peculiar topography of southeastern Edmonson County may be understood, a brief exposition of the principles of cave formation

will be given and later a discussion of specific features of the various caves will be included.

Sink holes and caves are intimately associated. Sink holes are surface features which are plainly shown upon the topographic maps, while caves are entirely subterranean and of themselves produce no effect upon the surface configuration of the country. Sink holes vary greatly in size, depth and outline but are characteristically funnel shaped and, unless clogged, drain through an opening in the lowest part. The funnels of small or shallow sink holes are in most cases developed largely in the soil which has been washed down into crevices in the rocks and carried away. Some of the larger and deeper sink holes, and particularly those with vertical walls, have probably been produced by the collapse of the roof of an underlying cavern. Sink holes are always connected with underground channels in the rock, which are called caves if they are of sufficient size to be entered. Most caves have sink holes leading into them, although this is not always the case.

Sink holes and their associated caves are only developed in regions which are underlain by soluble rocks, of which limestone is much the most important. Calcium carborate, which is the chief constituent of limestone is slightly soluble in pure water, approximately 75,000 parts of water being required to take into solution one part of calcium carbonate. Rain water absorbs carbon dioxide, which is present in small quantities in the air, and these carbonated waters act upon limestone to produce calcium bicarbonate thus:

Calcium Carbonate		Carbon Dioxide		Water		Calcium Bicarbonate
$CaCO_3$	+	CO_2	+	H_2O	=	$Ca(HCO_3)_2$

The resulting calcium bicarbonate is some thirty times as soluble as the carbonate and the solubility is even further greatly increased if carbon dioxide is present in the water in excess. In order that the degree of solubility of limestone in rain water may be visualized, it may be stated that the amount of water

which falls as rain upon one acre of land in Edmonson County, in the course of a single year, is capable under favorable conditions of dissolving some twenty-five or more cubic feet of rock. Sink holes and caves are developed to their maximum perfection in dense and massive limestones of fairly pure composition, as such beds are practically impervious to water except along fissures or bedding plains, and consequently solution is localized along certain lines. Comparatively porous limestones which offer free passage for the water in all directions do not commonly develop sink holes and caves unless, for some reason, the circulation of the water is concentrated locally.

Nearly all stratified rocks are cut by joints or fissures roughly vertical, which commonly occur in two systems of approximately parallel joints oriented nearly at right angles to each other. Such joints offer avenues whereby the water which has soaked into the soil may penetrate downward into the underlying limestone. As the water descends along the joints, solution takes place, they are enlarged and crevices are formed. The intersection of two joints which cross each other is apparently a particularly favorable spot for the penetration of water into the limestone. In such situations more or less circular openings are dissolved instead of the long narrow crevices produced along single joints.

Water which finds its way into the joints of the rock descends until its downward progress is brought to a stop. Such a halt may commonly be the result of one of two causes: first, a bed, such as shale, which is impervious to water may be encountered; or second, the ground water table, or the depth at which all the openings in the rock are filled with water, may be reached. In either case, when the downward movement of the water is brought to a stop, lateral movement begins and channels are dissolved out along the bedding plains or in porous layers in the limestone.

The downward and lateral movement of water in the limestone is at first slow and a large part of the rainfall is carried off by surface streams, but as solution enlarges the channels a

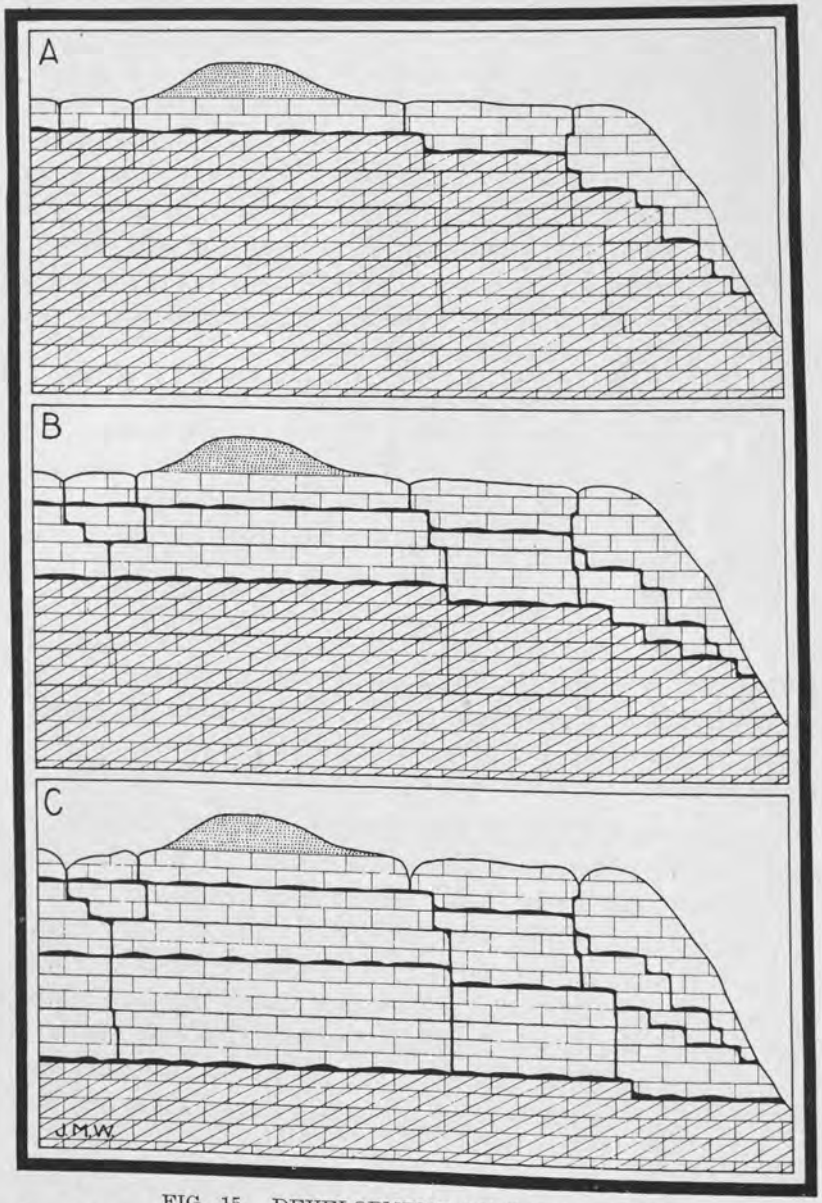

FIG. 15. DEVELOPMENT OF CAVE LEVELS.
This diagram illustrates the manner in which secondary drainage channels way reduce the ground water table (shaded) to local base level.

larger portion of the surface water finds its way into them and their development becomes more rapid. Soil washed into these openings furnishes the water with sand and sharp pieces of flint, enabling the underground streams to cut as well as dissolve their way, and large sink holes connected with caves may develop.

At the surface of the ground water table, the greatest tendency for motion of the water is in a lateral direction. Slow circulation, however, also takes place downward and outward below the ground water table. Under normal circumstances, such circulation is slow, but this slow motion serves to allow the water to accomplish a relatively greater amount of solution of the limestone. The slowly moving water below the ground water table is more intimately in contact with the limestone on account of its distribution throughout the minute openings in the rock. It is also in contact with the limestone for a longer time than the water in the freely drained channels above and consequently it approaches much nearer to complete saturation. The slowly moving water below the water table gradually enlarges the small openings in the rock by solution and its movement is slowly concentrated along certain lines until tiny channels are developed. Such channels offer freer movement for the underground waters than the natural openings in the limestone and as soon as they are opened they serve as lines of drainage for the surrounding rock. With the concentration of movement along these lines, the channels are rapidly enlarged and as soon as their capacity becomes sufficient the ground water table is brought down to their level. As this process progresses the waters flowing in the channels developed at the surface of the ground water table seek new passages downward and the old channels are eventually left dry and deserted above.

The level of the ground water table may also be lowered by the action of the streams which flow in channels at its surface. These streams, by both solution and erosion of their beds, cut themselves deeper into the limestone and drain the smaller openings of the rock about them. By repetitions of these processes, the exact nature of which is determined by local conditions, the level of the ground water table is steadily reduced until the base-level for the region is reached and the process stops.

Slight movement of the water below the ground water table, even where this is at base-level, still takes place and openings in the rock are enlarged by solution, but the main drainage channels cannot be reduced below this level.

Probably the most important process in the development of great cave systems is that of the formation of secondary channels below the level of the ground water table. This process is dependent upon the circulation of the ground water. It is strongly influenced by the hydrostatic head, which in turn is determined by the height at which the ground water table locally stands above the base-level. The fluid circulation may reasonably be assumed to be most rapid in a thick series of limestones standing high above the controlling surface drainage lines.

By way of summary, the following points are most important in connection with the extensive development of underground drainage by means of sink holes and caves:

1. Sink holes and caves are best developed in a thick series of massive, compact and rather pure limestones which lie high above the main lines of surface drainage.
2. Surface waters diverted underground through sink holes and crevices are carried off through primary channels which are developed at the surface of the ground water table.
3. These primary channels, by both solution and erosion, cut themselves deeper into the limestone and lower the ground water table.
4. Secondary channels develop below the ground water table, which they eventually lower to their level.
5. The position of streams in primary channels is unstable when secondary channels have reduced the level of the ground water table below them, and they seek new courses at a lower level.
6. The ground water table is continually lowered by downcutting of the primary channels and the development of secondary channels until the local base-level is reached.
7. Complete stability of underground drainage is attained only when the ground water table has been carried down to base-level and the underground streams have become adjusted at this level.

Physiographic Provinces

The same general lines which divide Edmonson County into seven topographic areas serve also to separate it into seven physiographic provinces. The differences in the topography of these divisions are the results of the same succession of

erosional activity in areas of different stratigraphic and structural conditions. The topography of these seven subdivisions has been described briefly in Chapter III and it remains only to discuss those influences which have resulted in these various types of topography.

Southern Sink Hole Plain. The Southern Sink Hole Plain owes its existance to the much greater ease with which limestone is eroded than is sandstone. After the removal of the Cypress was effected by erosion which produced the peneplain represented probably by the highest points in this region, such as Pilot Knob (southeast of Smiths Grove), the underlying limestones were easily attacked and the surface lowered more rapidly than in the area to the north over which the Cypress still extended as a resistant protective covering. From the time at which the streams first dug through the Cypress sandstone in this portion of the county, sink holes have probably been present continuously.

The sink holes may be developed now to a greater extent than ever before as it is known that this area was in part drained by surface streams whose development has already been traced. Even though the drainage was formerly carried mainly by surface streams, sink holes were present. The sandstone blocks which occur in the railroad cut at the west border of Glasgow Junction, just one mile east of the Edmonson County line, contain Middle Chester fossils and are probably blocks which slumped down into one of the early sink holes of which no trace now remains. The limestone beds in which this particular sink hole was formed have been entirely eroded and only the blocks of more resistant sandstone remain.

Dripping Spring Escarpment. Although previously regarded simply as an erosional scarp, the Dripping Spring Escarpment is possibly due to an east west fault which may be present close along the southern side of this scarp. The down throw of this hypothetical fault must have been on the north, and originally, therefore, a fault scarp facing to the north was formed bordering a southern higher land surface—practically the reverse of the situation which is observed today. The displacement along this fault was such that the Cypress Sandstone upon the

south was situated above the level at which an early peneplain was developed and consequently it was entirely removed. On the north of the fault, however, the Cypress lay at a lower elevation, below this peneplain level, and therefore was not removed.

With the initiation of subsequent erosion it is assumed the region upon the south, underlain only by a thick series of limestone strata, was more readily attacked and more rapidly eroded than the area to the north which would have been protected by the resistant Cypress Sandstone. In this manner the scarp marking this fault might have been transferred from its original and normal position to the north by more rapid erosion of the uplifted side.

Interior Plains. The region of the Interior Plains was almost completely eroded down to base level at the 700 foot stage. During this cycle of erosion the Pottsville was stripped from a large portion of southeastern Edmonson County and the underlying less resistant Chester formations were exposed at the surface. With the following rejuvenation erosion again became active and the Litchfield and Glen Dean formations were rapidly removed and a surface gently sloping to the northwest was developed upon the Hardinsburg Sandstone, which was the first resistant horizon to be reached. The Interior Plains are, therefore, a dip slope developed upon the Hardinsburg Sandstone extending from the 700 to the 600 foot base-levels and below which the streams have been entrenched due to subsequent rejuvenation.

After the development of the 700 foot level, the northwestward flowing streams, which were lowering their channels in the Litchfield and Glen Dean formations, were more advantageously situated than the southward flowing streams, which formerly drained this area and cut their way through the Cypress in the Dripping Spring Escarpment. As a result of the more rapid lowering of their channels, the northwestward flowing streams may have captured a small part of the drainage of those which formerly flowed away to the south.

Valley Sink Area. The Cypress Sandstone is a formation highly resistant to erosion and from the time it was first exposed at the surface until the present it has remained as an efficient protective cap throughout the Valley Sink Area. During the

period of erosion which resulted in the development of the 700 foot level the Cypress was first cut through in that portion of the county northeast of the Elko-Chaumont Ridge. The depressions which at present appear as Houchins Valley and the valley sinks lying to the southwest of the Mammoth Cave Ridge were formed at this time and since then but little further removal of the Cypress has been effected. The bottoms of these two valleys which were cut through the Cypress were reduced practically to a regional base-level at the 700 foot level and when the subsequent rejuvenation occurred, sink holes developed along their courses and their waters were carried away through underground channels, some of which are to be seen as the 600 foot levels in the caves.

At Turnhole Bend the Cypress lies at an elevation below 700 feet and it was, therefore, not completely cut through during the development of the 700 foot level. The presence of this sandstone at such an elevation at the mouth of Woolsie Hollow was probably most effective in reducing the rate at which the stream formerly flowing through this valley, could cut down its channel, since the removal of the Cypress Sandstone was most rapidly accomplished by a process of undercutting extending up stream from Green River. At the time of the development of the 700 foot level, therefore, the streams which later cut Woolsie Hollow and its tributary ravines were probably still flowing throughout their entire courses upon the Cypress, having nowhere cut through this formation except, perhaps, in the upper part of Cedar Spring Hollow where drainage was later captured by the headwaters of Rays Branch, now entering Barren River four miles north of Bowling Green.

With the rejuvenation which followed the development of the 700 foot levels Woolsie Hollow and its tributaries were rapidly cut through the Cypress and reduced nearly to base level at about 600 feet. Since this time very little erosion of the Cypress Sandstone has been accomplished anywhere within the Valley Sink Area. With the rejuvenation which followed the development of the 600 foot level sink holes developed at various places along Woolsie Hollow and its tributaries and the surface streams were captured by underground channels in an exactly similar

manner to that which occurred one stage before in the case of the two valleys to the northeast. Since this time but little change has been effected in the topography of the Valley Sink Area.

Knob Belt. During the period of erosion which culminated in the development of the 800 foot base-level the Pottsville was stripped from a considerable area in the southeastern portion of Edmonson County. During the next period of erosion this process was continued to the west of Turnhole Bend. Above these two base-leveled surfaces and the gentle slopes which in a few places connected them, there remained knobs, or erosion remnants, capped by the resistant basal Pottsville sandstone. Since the development of the 800 foot level north and east of Turnhole Bend and the 700 foot level to the west, but little further erosion of the Pottsville has taken place and the knobs which were produced at these times remain to the present, although the old terraced surfaces have been destroyed to a large extent by more recent erosion.

Hilly Country. The Hilly Country constitutes essentially that portion of Edmonson County, throughout which the Pottsville lies as a continuous cap upon the hills and ridges. In the eastern part of this division erosion has cut through into the underlying Chester beds, but to the west the base of the Pottsville dips down beneath the level of the valleys and the Mississippian formations are not exposed. The Hilly Country possesses a gentle regional dip to the west, descending from over 900 feet in the eastern part to less than 800 feet in the northwestern corner of the county.

Various portions of the Pottsville series are widely different in the resistance which they offer to erosion. The most resistant beds occur at the base where a massive sandstone is extensively developed. The higher strata become shaly and are more readily removed. The general westward dip of the beds throughout the Hilly Country has resulted in the presentation to erosion of younger and younger beds in a westward direction. Consequently at a stage in the erosional history of the county, during which the resistant massive basal Pottsville standstone was being eroded in the eastern part, higher less resistant shaly beds were present at the surface farther to the west. As a result, erosion progressed

much more rapidly in the western part of this area than in the eastern, this difference being magnified with the passage of each successive period of erosion.

The 800 foot base-level was well developed throughout the Hilly Country, the only noteworthy remnants which were not reduced to this level lying upon the east side of Nolin River, where the basal Pottsville sandstone is present at its highest elevation. The 700 foot level was well developed east as far as Nolin River and extensive flats were also developed in the valleys of Brier and Longfall Creeks, which lie upon the north side of the channel in which the massive Pottsville sandstone occurs. At the 600 foot base-level extensive flats developed along Bear, Sunfish and Reedy Creeks, cut upon the shaly beds of the Pottsville, while along Nolin River their development was much less notable, due to the protective presence of the lower sandstones upon the hill tops. The next period of erosion has left flats upon both sides of Green River at the west county line and at the junction of Sunfish with Bear Creek, while no evidence of its existence is to be discovered farther east.

The westward dip of the beds in the Hilly Country is directly reflected by certain topographic features, such as the gentle westward slope of the flat hill tops which intervene between Nolin River and Bear Creek in the neighborhood of Bee Springs and also the line of hills which occur upon the west side of Sunfish Creek, standing as a much dissected cuesta like ridge.

Sunfish Area. The Sunfish Area is physiographically simply a subdivision of the hilly country, but as it is much different in its topographic appearance it is given separate consideration. This area, which is largely included between Bear and Sunfish Creeks, is essentially a dip slope produced by the stripping away by erosion of the shaly Pottsville beds which overlie the lower resistant sandstones. The beds which form the surface in this area are the same ones which occur upon the hill tops in the vicinity of Bee Spring and, were it not for the valley of Bear Creek, one continuous gentle slope would descend from Bee Spring to Sunfish. A remnant of the beds which have been stripped from this surface remains in Little Mountain, whose strata were at one time continuous with those which occur in the

hills west of Sunfish Creek and also upon the hill tops at Sweeden.

Edmonson County Caves.

The five important caves now known, which are partly or wholly within Edmonson County, all underlie the northeastern part of the Valley Sink area or the adjoining portion of the Knob Belt on the south side of Green River. Mammoth Cave is by far the largest and best known. It was discovered some time prior to 1797, as it is mentioned in a deed filed at this date in Bowling Green. Mammoth Cave may be reached by two entrances situated three and one quarter miles apart. It is said to consist of five levels and it is claimed that the length of the explored passages totals 150 miles, but doubtless this is too great an estimate. Eight miles of passages are shown on the accompanying map.

Salts cave, which was discovered before 1875, is a little more than a mile in length and lies half within Edmonson and half within Hart Counties. It may be entered at either end and passes a little west of north completely under the ridge about one-quarter mile west of Chestnut Grove School in Hart County.

Colossal Cave, which lies about midway between Mammoth and Salts Caves, was discovered in 1895. It also may be reached by two entrances, which are about two-thirds of a mile apart. Great Onyx and Great Crystal Caves, both unusually beautiful caverns, were discovered about 1915 and 1920 respectively. They are probably smaller than any of the other three. These caverns occur northwest and north of Salts Cave, underlying hills which rise directly from Green River, and each of them possess but one known entrance.

All of the Edmonson County caves underlie hills or ridges, but their exact trend is not indicated by any surface features. The caves as they are known are probably only a small portion of a great interlocking system of underground channels, which formerly drained the surrounding country. The cave passages in most cases end in "sand breaks" as they are known locally. These are, without doubt, the lower portions of sink holes which have become filled with fallen blocks of the Cypress Sandstone

which caps the ridges in this vicinity. Could these obstructions be passed the caverns, doubtless, would be found to continue onward.

Cave Levels. Surveys show that many of the cave passages have a general northwesterly trend, but others equally large but less numerous, and in most cases not as long, extend approximately at right angles to these. This is rather suggestive that jointing of the limestone has played an important part in determining the courses pursued by the underground channels, though no actual observations in the caves themselves have been made to test this apparent relationship.

Several levels are present in each of the Edmonson County caves. Profiles of Great Onyx, Great Crystal, Salts and Collossal Caves are shown in figure 10. Unfortunately no surveys of this type are available for Mammoth Cave, which on account of its much greater extent, might be expected to yield the most interesting results. From the data at hand, however, three well defined levels may be recognized at about 500, 600 and 700 feet respectively, while less well defined levels exist at 550 and 650 feet. These levels are all dry but in a few places the descent may be made to streams such as the Echo River of Mammoth Cave, the elevation of which is practically the same as that of Green River.

These various cave levels were each formed by an underground stream which formerly flowed through it, the uppermost first and the lowest last. With the formation of each lower level the water formerly flowing in the higher ones was diverted and these were left high and dry until at the present time the water which drains from the surrounding country flows through still lower channels which can only be reached at a few points.

Cave Passages. The cave passages are of two general types. The first is characteristically narrow and high, with ragged polished walls. These passages were probably formed by the downward erosion of streams which developed at the surface of the ground water table as has been explained on a previous page. These streams flowed through channels which were developed above the base-level and were able therefore to cut their way downward.

The second type of passage is characterized by flat or roughly arched roofs and walls which have developed along

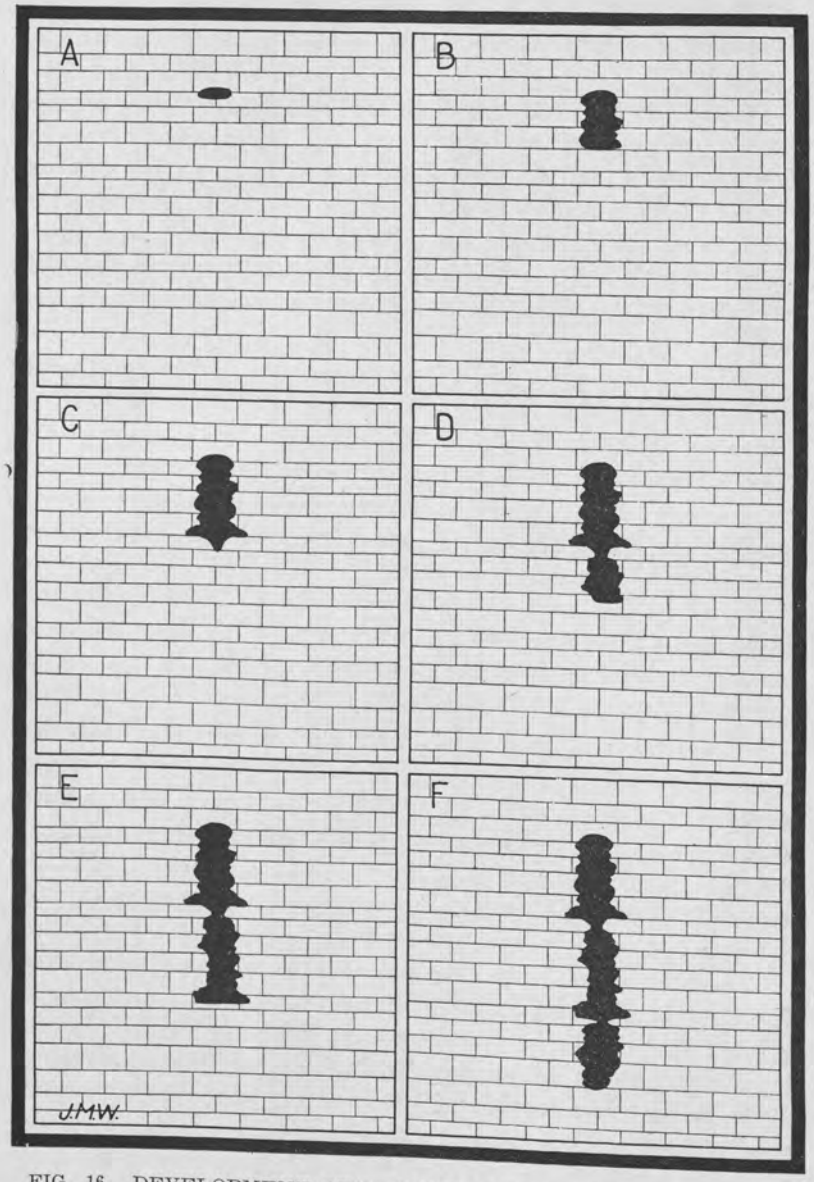

FIG. 16. DEVELOPMENT OF NARROW AND HIGH TYPE OF CAVE PASSAGE.

fractures in the limestone. This type of passage sometimes opens out into enormous chambers such as the Rotunda and Grand Central Station in Mammoth Cave. The floors of these passages are generally strewn with fallen blocks of limestone of varying dimensions, and great masses of debris rise in many of the wider stretches. These passages were probably formed by streams which flowed through channels developed at base-level. Under such conditions the streams could not erode their channels deeper and their energies were devoted to lateral cutting and the undercutting of certain strata of the limestone removed their support and allowed them to collapse. The fallen fragments were gradually removed by the streams, this process being repeated many times, the passages being enlarged by the falling in of the roof, layer by layer.

The cave profiles illustrated in figure 10 show that the passages are more or less undulating, and many short up and down grades occur. Obviously when these passages were occupied by streams, their floors must have been approximately level and the inequalities which are now present are probably due to the falling of blocks of limestone from the roofs subsequent to the abandonment of the channels by the streams which formed them. No definite examples can at present be cited in illustration of this explanation as underground observations are lacking, but it is improbable that this process has produced most of the steeper or higher grades which are encountered at many places. These latter slopes may be subsidiary channels developed to connect different cave levels.

The sharpness of many of the breaks along the walls and the freshness and angularity of most of the fallen blocks of limestone is striking, and suggests that these fragments have fallen from the roof in comparatively recent time. The burnt ends of torches used by the Indians also have been found beneath piles of fallen debris in some places. In spite of all this, the cave guides and explorers state emphatically that no blocks have fallen since the caves have been explored. It seems highly probable therefore that a large portion of the material which strews the floor in certain passages of the cave, fell at the time of the New Madrid earthquake in 1811. Severe shocks were felt throughout Western Kentucky and Shaler states that in the town of

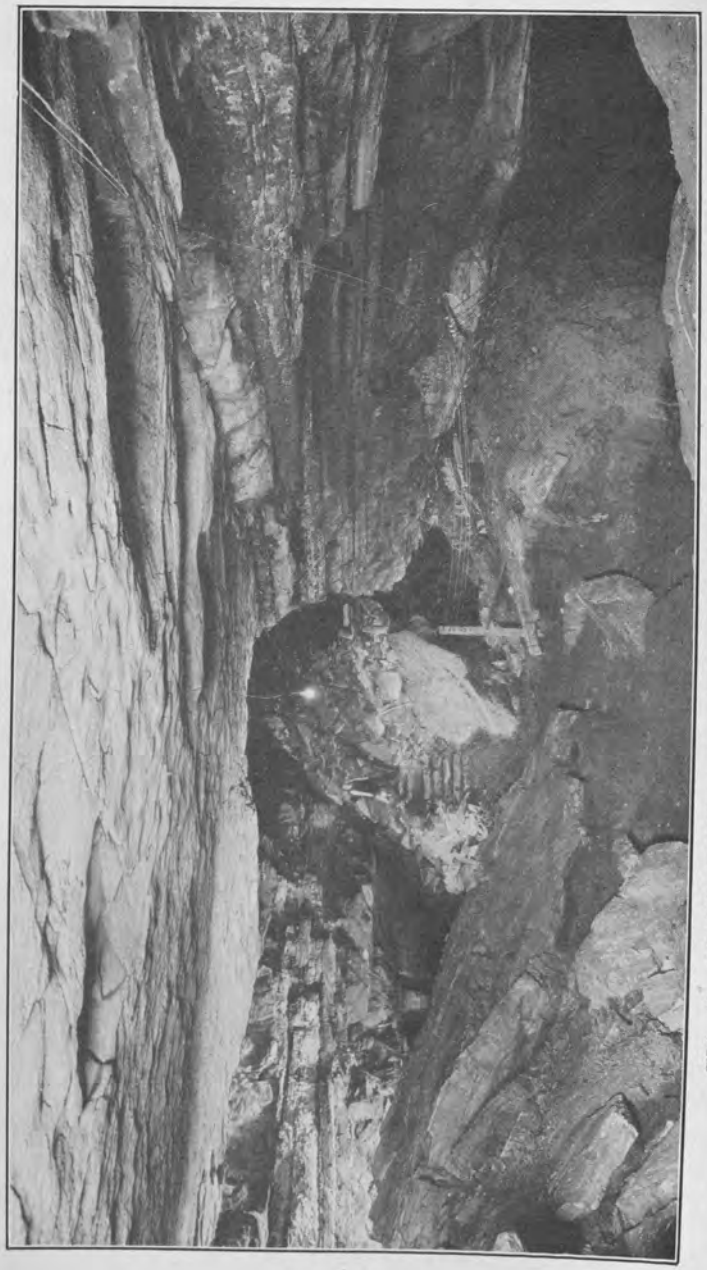

FIG. 17. GRAND CENTRAL STATION, NEW ENTRANCE TO MAMMOTH CAVE.
Note the flat roof and the masses of fallen debris which lie upon the floor.

Leitchfield, which is located 23 miles northwest of Mammoth Cave, several chimneys of great solidity were overthrown nearly to their base.[3]

As has been noted already the cave passages are now apparently restricted to regions beneath the hills and ridges but the original development of underground channels was not confined to these areas. The adjacent valleys have been cut down below some of the higher cave levels and only those portions which existed beneath the hills have been preserved. The lower levels undoubtedly are connected yet with passages which extend beneath the valleys, but probably these are employed still to some extent in carrying off the drainage or have been choked with debris carried down into neighboring sink holes and consequently are inaccessible or blocked.

Cave Entrances. In general, cave entrances are of either one of two types. The first type leads steeply, or in many cases, vertically, downward from a sink hole which drains into a cave passage below. Almost any sink hole, were it not choked with debris, would prove to be an entrance of this kind. The other type has been produced by the downward cutting of surface erosion until a cave passage is intersected. Such entrances almost always occur upon hillsides, the main entrance to Mammouth Cave being a good example. Such entrances generally lead downward at a more or less steep angle for some distance until the cave passage is reached. It is obvious that the cave passage at one time must have opened upon the hillside at a level with its extension under the hill, but with the passage of time ledges from the roof have fallen and a pile of debris developed below. In this manner the cave entrance has migrated up the hillside. A shaft sunk at the mouth of Wyandotte Cave in Crawford County, Indiana, passed through a pile of debris 60 feet thick before the solid rock floor was reached[4]

Pits and Domes. The pits and domes are probably the most striking features to be observed in the Edmonson County caves. Pits and domes are the same, the name simply depending upon whether they are viewed from above or below. They are roughly

[3] N. S. Shaler: "Reports of Progress," Geol. Surv. Ky. N. S., Vol. 3 1877, p. 237 (Par. 3, p. 109).
[4] F. C. Greene, "Caves and Cave Formation in the Mitchell Limestone." Ind. Acad. Sci. Proc. 1908, p. 181.

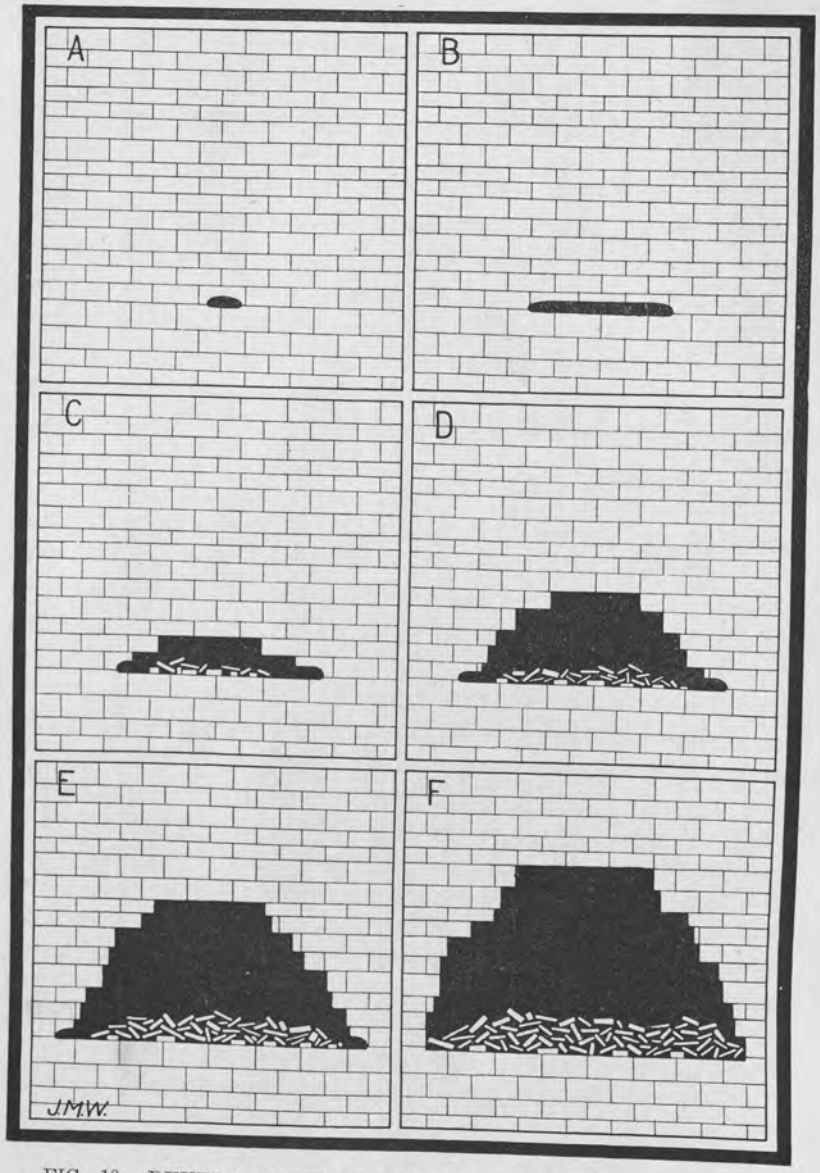

FIG. 18. DEVELOPMENT OF CAVE PASSAGES WITH FLAT OR ROUGHLY ARCHED ROOFS.

circular wells 15 feet or more in diameter with vertical smooth walls upon which cave onyx is deposited in many places in giant flutings. In form they closely resemble the lower portions of some sink holes but they do not extend to the surface. In many cases they connect two or more cave levels. It is probable that these pits or domes are essentially underground sink holes, developed in the channel of an underground stream. The formation of a secondary channel may have lowered the ground water table and left the stream flowing through a primary channel perched high above. The stream so situated would seek a descent to the lower level, and apparently those positions where the two channels lay one directly above the other offered the easiest passage, and the water gradually enlarged a cross joint down which the upper stream eventually found its way.

Cave Deposits

The mineral matter deposited in caves is of three general types: first, material deposited largely from suspension in cave streams, or silt; second, material deposited in a more or less amorphous condition from solution, largely from slowly descending surface waters, or travertine; third, material deposited from solution in well crystalized condition, as gypsum, calcite, etc.

Cave Silt. The floors of many of the passages of the Edmonson County caves are covered with a layer of fine silt up to a depth of 10 feet or more. These deposits are composed largely of fine, somewhat angular quartz grains, together with a subordinate amount of fine clayey material and the whole is stained with iron oxide to a reddish brown color. These silts are really sediments which were deposited by streams which formerly found their way into these parts of the caves. In all probability, such sediment was not deposited along the main drainage channels which existed at any particular time, for the underground streams, confined as they were, would have been capable of keeping their channels entirely clear.

It is possible, however, that at certain times heavy rains so flooded the underground drainage system that the main lower channels could not accommodate the whole volume of the water and it backed up into one or more of the upper levels, which were at ordinary times, dry and deserted. This may well have

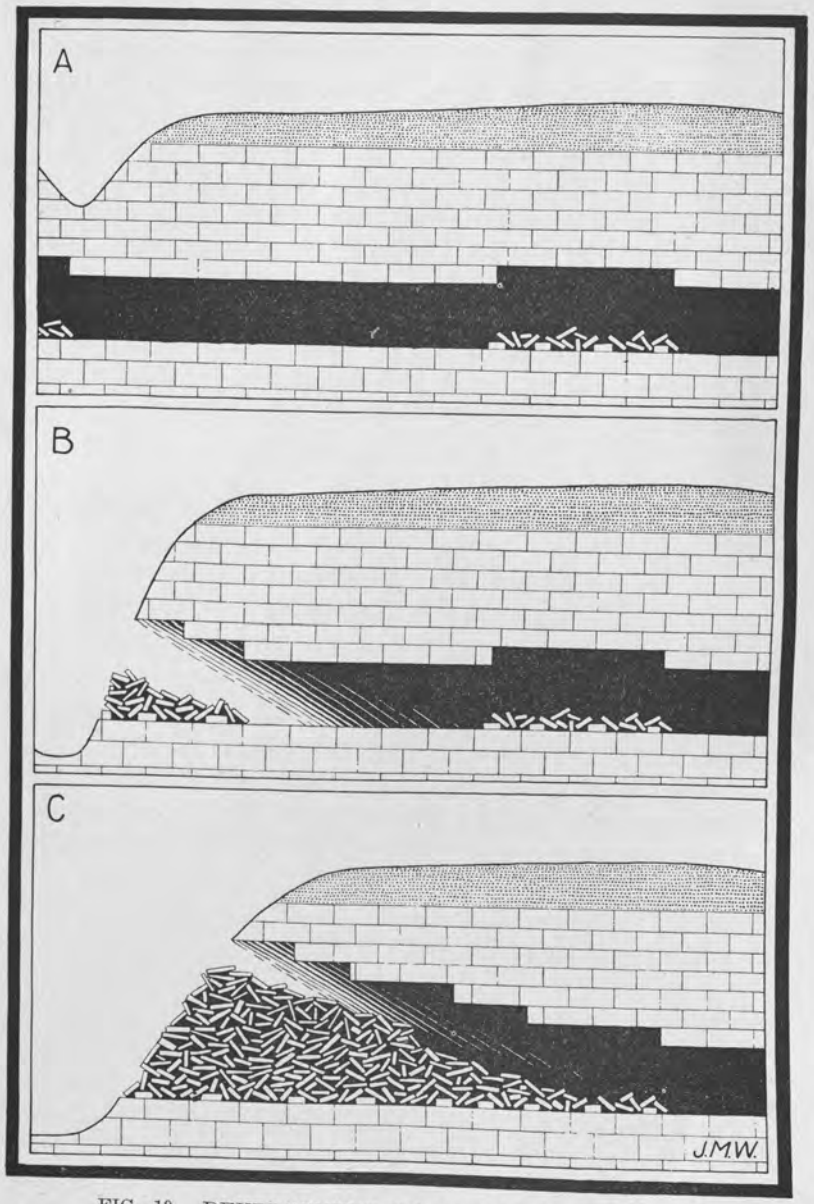

FIG. 19. DEVELOPMENT OF A CAVE ENTRANCE.
The upward migration of entrance is caused by the collapse of the roof.

taken place particularly in the early stages in the development of a lower drainage level, and before the new channels had become considerably enlarged. At such flood stages, large quantities of surface waters would find their way into the caves. These waters would carry considerable amounts of sediment derived from the slopes and sides of the sink holes through which they drained, and with the slackened conditions prevailing in the upper cove levels due to the backing up of the water from the lower channels, this suspended material would be deposited.

In some places, these cave silts carry considerable amounts of nitrates. These salts, which are extremely soluble, were not deposited from the cave waters but were without doubt, derived from the excretion of bats which inhabited the caves in great numbers. Such material would accumulate very slowly and the presence of nitrates in amounts sufficient to warrant their being leached out for the manufacture of gunpowder as has been done in the past, is strong evidence that a condition of dryness has prevailed in these portions of the caves for many thousands of years.

In certain portions of the lowest cave levels, there are accumulations of dark gray to black muds, much different in appearance from the silts mentioned above. These darker sediments occur only in those portions of the caves, as in the neighborhood of Echo River in Mammoth Cave, which are flooded by back water from Green River when this stream is at its high stages and they are without doubt derived from this source.

Travertine. The solvent action of carbon dioxide bearing waters has already been discussed and the long continued action of such solution has resulted in the formation of limestone caves. By a reversal of this process, caves which have already been formed, later may be partially or even completely filled up. Streams flowing through cave passages, move comparatively swiftly and their waters are rarely in contact with the limestone for a sufficient time to dissolve calcium carbonate to the point of saturation, but waters which enter the limestone at the surface and travel downward toward the ground water table through the pores and cracks in the rock move very slowly through these minute openings. They are in intimate contact with the limestone for a comparatively much longer time and in most cases

become completely saturated with calcium carbonate. When such downward moving saturated water enter one of the higher levels of a cave, the constant movement of the air evaporates either a part or a whole of the water, and the dissolved calcium carbonate remains behind.

For the deposition of the calcium carbonate from the descending waters, two conditions are necessary; first, the waters must find their way into a cave passage or chamber, and second, the air which slowly circulates through this passage or chamber must be dry. If the descending waters did not enter an open cavern they would continue downward to the ground water table and then take their place in the slow circulation of these waters to be eventually drawn off into the surface streams. Finally their load of dissolved material would be carried to the sea.

No deposition from solution can take place in those portions of the cave to which the descending waters do not penetrate; and unless the air in that portion of the cave into which descending waters find their way be dry no evaporation can occur. The lower levels of the caves, through which the underground streams flow, usually contain humid air and consequently the deposition of calcium carbonate in these parts is most exceptional. Those portions of the caves, therefore, which are most favorable for the deposition of calcium carbonate from the descending waters are the higher dry levels which lie close to the surface. This is well illustrated in Great Onyx Cave, the entrance of which leads directly from the hillside into a chamber exhibiting a marvelously beautiful aggregation of stalactites and stalagmites, these features being largely confined to the portion of the cave which occurs directly beneath the hillside and nearest to the surface. Further back, along the passages, such deposits are much less abundant.

In most cases the calcium carbonate bearing waters from the surface find their way into the caves along joints in the limestone. They pass slowly downward through these joints and when the cave is reached drops are formed which hang from the roof until they attain sufficient size to fall. During the time while the drops hang suspended from the roof a small portion of the water is evaporated and a part of the dissolved calcium carbonate is deposited. In this way stalactites are formed and

and at many places in the cave, rows of these downward projecting, icicle-like forms mark the joints from which the waters issue.

As a drop of water hangs from the roof of a cave, evaporation causes the deposition of a portion of the dissolved calcium

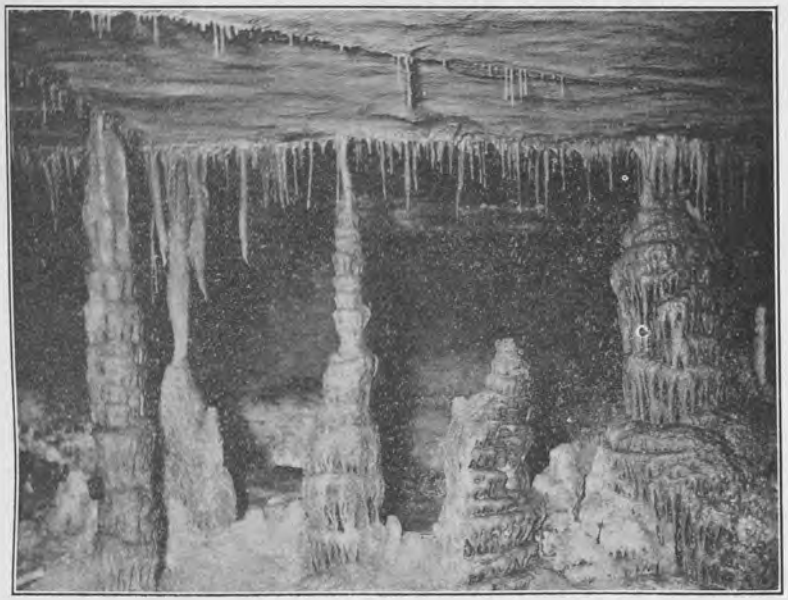

FIG. 20. STALACTITES IN GREAT ONYX CAVE.
This view shows the grouping of stalactites along joints in the limestone roof.

carbonate, in a ring about the margin of the drop. With each successive drop more calcium carbonate is deposited around the edge and the initial ring is slowly built downward into a tube. Young stalactites are, therefore, slender tubes the size of a lead pencil or smaller, through the central opening of which the water passes. As the length of these tubes is increased by the deposition of calcium carbonate upon the lower end, so also is the interior gradually filled up until there is no longer a passageway left, through which the water can pass. Tubular stalactites rarely attain a length greater than about six inches. When the central passage through a young stalactite has become filled the waters slowly trickle down upon the outside of the small pendant formation. They are now subject to evaporation through

FIG. 21. PHONOGRAPH HORN IN GREAT ONYX CAVE.

This is travertine deposit produced by the comparatively rapid downward flow of calcium carbonate saturated waters.

out the whole time of their downward course from the cave roof, and calcium carbonate is deposited all over the surface of the stalactite, causing it to grow in diameter as well as in length and

it finally takes on the shape of a slender tapering rod, or an elongated inverted cone.

If the calcium carbonate bearing waters descend so slowly that they completely evaporate as they hang from the cave roof, all of their dissolved material will be deposited upon the stalactite, but in most cases this does not occur. Drops form, hang suspended for a time and then fall to the floor of the cave, splash in all directions and completely evaporate. Under such conditions only a portion of the calcium carbonate is deposited upon the stalactite, the remainder, and usually the greater part, being deposited upon the floor of the cave. In this manner, while the stalactite is being formed hanging from the roof of the cave, a stalagmite is built up upon the floor. The stalagmites are in most cases of greater diameter and greater mass than the corresponding stalactites, due to the fact that a greater portion of the water falls to the floor of the cave than is evaporated upon the stalactite. Continued downward growth of the stalactite and upward growth of the stalagmite will eventually result in their junction and a column rising from floor to roof will be formed.

The relation which is observed to exist between the size of a stalactite and its corresponding stalagmite gives evidence concerning the rate at which they were formed. If the waters descended comparatively rapidly, a much smaller proportion would evaporate upon the stalactite than would fall to the floor and consequently the stalagmite would be comparatively of much greater size. With slower movement of the waters a larger proportion would evaporate upon the stalactite and the difference in size between it and its stalagmite would be less pronounced.

During the growth of a normal stalactite, after the filling of the central tube, the waters flowing downward in thin films are more or less evenly distributed over the surface resulting in the formation of a roughly cylindrical or tapering pendant mass. If, however, after the clogging of the central passage the path of the water is for some reason confined to a single side of the original tube, deposition of additional calcium carbonate will take place only along this side and a thin sheet will be formed with an inclined edge along which growth takes place, which may curl and twist in a most fantastic manner. Such drapery-like forms are well exhibited in Great Onyx Cave.

At many places in the caves calcium carbonate bearing waters enter in such positions that instead of dripping from the

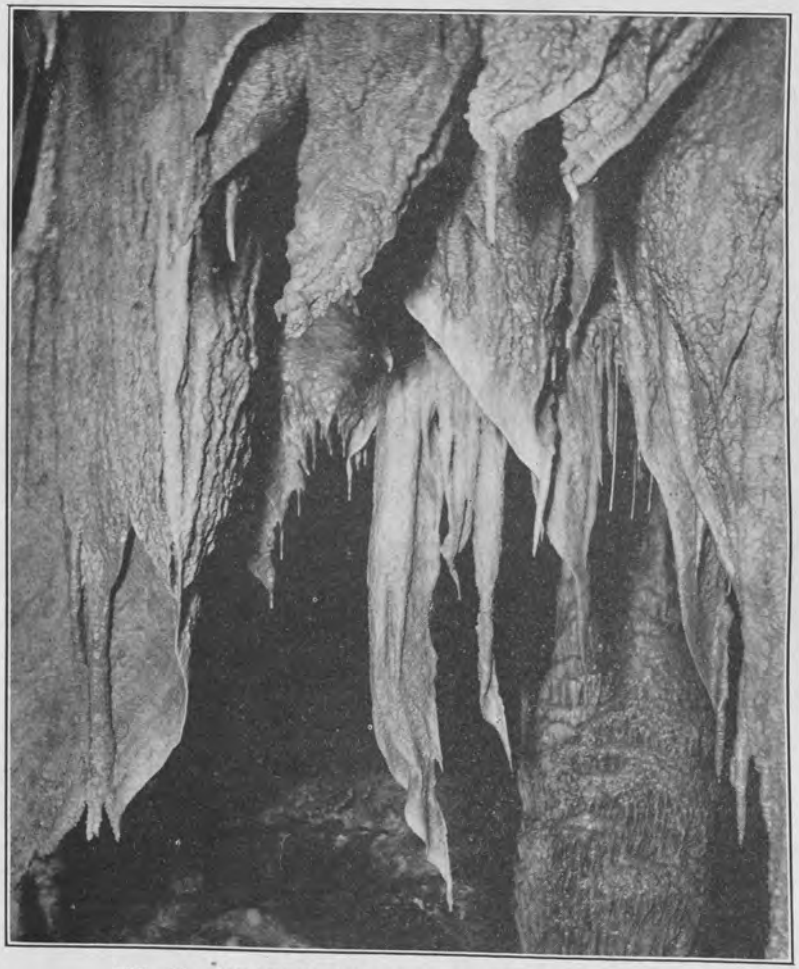

FIG. 22. DRAPERY DOME IN GREAT ONYX CAVE.
A modified form of stalactitic growth.

roof and forming stalactites and stalagmites, they flow downward from the cave walls upon which, as a result of evaporation, calcium carbonate is deposited.

The several types of calcium carbonate deposits which have been described are included under the general term *travertine*,

which is applied to many calcareous deposits which have resulted from evaporation or decrease of pressure or temperature. Cave travertines are popularly known as "onyx" although this latter term is properly applied only to certain siliceous deposits, and

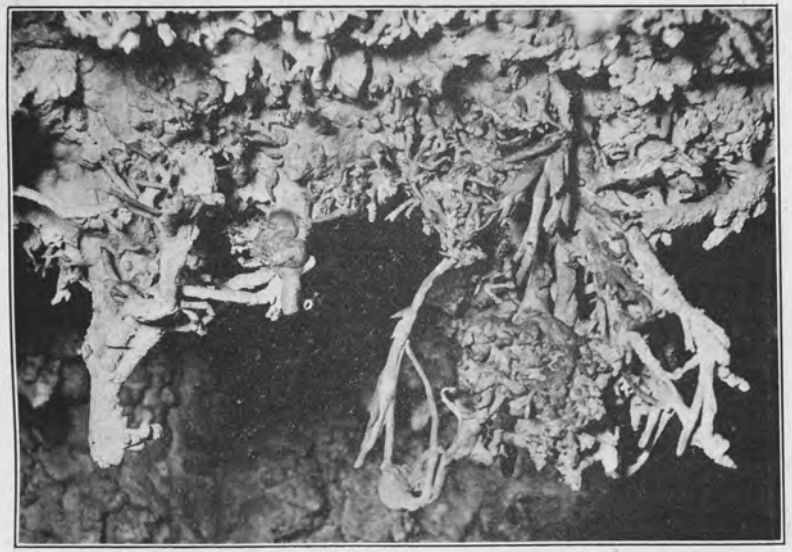

FIG. 23. HELECTITES IN GREAT ONYX CAVE.
The detailed branching and complicated form of these peculiar growths is well shown here.

the terms "cave onyx" or "onyx marble" have been suggested to take its place.

Cave travertine is deposited in either an amorphous or very finely crystalline form, but broken sections of large stalactites and stalagmites show that recrystallization has taken place and in many cases these are transformed to interlocking aggregates of calcite crystals up to one quarter of an inch in size.

While cave travertine is composed largely of calcium carbonate, certain impurities are present in most cases. The most important is iron, but organic matter and fine silt are generally present to some extent. These impurities are brought in by the same waters which carry the calcium carbonate, are deposited contemporaneously and are intimately admixed with this substance. Changing conditions which affect the source and movement of the descending waters result in the variation from time

to time of the impurities which they contain, and this produces the color banding which is so commonly observed. Such banding is well exhibited in the travertine draperies of Great Onyx Cave and is best observed when a lamp is held behind them.

Another type of travertine deposit occurs abundantly in some parts of the caves which is known as *helectites*. These formations are composed of material which is entirely similar to that which makes up the stalactites, but the manner of their growth is different. The helictites grow downward from the cave roofs or outward from the sides of stalactites. As a rule they do not hang vertically but project downward and branch in a complicated fashion, some portions extending horizontally while, here and there, some parts of them have apparently grown straight upward forming a tangled mass of branching curved and interwoven stems of most peculiar appearance. The reason for the deposition of calcium carbonate in these forms is not known.

Crystals. Among the most curious and beautiful mineral growths which occur within the Edmonson County caves are the gypsum crystals which are to be seen upon the roofs and walls in some places in perfect, glistening white rosettes, or hanging from the roofs in curved and bent crystals, some of which are almost as delicate as feathers. This gypsum, or hydrated calcium sulphate, has without doubt been formed by the action upon limestone of sulphuric acid produced in the oxidation of pyrite which occurred in the shale or disseminated through the overlying Cypress Sandstone.

The gypsum masses which hang from the roofs of the caves are bundles of crystal fibers, each of which is strongly curved. Gypsum occurs in a similar form in caves in Indiana and also in France[5] and is known by the name of *oulopholites*. It has previously been supposed that the curvature of these bundles of gypsum fibers has been produced in some way by pressure, perhaps due to growth at the base, but microscopic examination of thin sections of the gypsum from Great Crystal Cave shows that this is not the case. Under crossed nicols the gypsum mass may be seen to be composed of a group of fibers which, in their relations to one another, suggest twinning. In a single field these

[5] Lacroix, "Mineralogie de la France" (1910), Vol. 4, p. 209.

fibers curve through an angle of 40° and yet each fiber extinguishes practically simultaneously throughout its whole length, proving conclusively that although the fiber is curved the

FIG. 24. THE CHIMES OF NORMANDY, GREAT ONYX CAVE.

These are slender stalactites covered with the peculiar branching and twisted helectites.

crystallographic axes are straight and, therefore, the curving of these aggregates has been produced by the original manner of growth and is not due to any sort of force, pressure or deformation. Why the gypsum should have grown in this manner is not understood.

In some portions of the caves gypsum is abundant as a crust one to one and one-half inches in thickness at the top of the deposits of cave silts. By capillary action gypsum bearing solu-

tions, which found their way into the silts, have been continually drawn upward to the surface, where the water has evaporated and the dissolved material has been deposited. In this manner the crust which is essentially a caliche was formed and has grad-

FIG. 25. GYPSUM CRYSTALS GROWING FROM THE ROOF OF THE NEW ENTRANCE TO MAMMOTH CAVE.

These curving clusters of snowy white fibers are of exquisite beauty.

ually thickened. This gypsum is plainly a fiberous crystalline mixture, containing abundant impurities of sand and clay.

Crystallized calcite in the form known as dog-tooth spar occurs in Great Crystal Cave. The crystals have grown as closely set elongated pyramids an inch or so in length from whose sides smaller crystals project in all directions, which gives them a very spiny appearance. Without doubt they crystallized from solution in pockets in the limestone which were continually filled with clear waters somewhat supersaturated with calcium carbonate.

Pleistocene Valley Filling.

Before the locks were constructed across Green River, slack water extended to the mouth of Honey Creek in Edmonson

County,[6] at which point the low water level of Green River was about 400 feet above the sea. From the junction of Honey Creek, Green River flows about 150 miles to its mouth, where the low water level of the Ohio River is about 330 feet above the sea.

FIG. 26. LAKE IN THE VALLEY OF CROOKED CREEK.

This small lake is elongated and narrow and occupies the level part of the valley from one side to the other. Pottsville bluffs which stand upon the eastern side are shown in the background.

The gradient of Green River in this part of its course is something less than six inches per mile, which is less than the gradient of the Mississippi between St. Louis and the Gulf. The gradient of Green River up stream from the mouth of Honey Creek is in strong contrast to the above as it rises 100 feet in about 60 or 70 miles. The locking of the river has somewhat obscured the natural gradient to the west of Edmonson County, while the lack of topographic maps makes accurate measurement of the rise to the east uncertain. The above figures, however, show conclusively that the former slack water at the mouth of Honey Creek marked the point of a sharp discordance in gradient, that to the east being between two and three times that which prevailed down stream.

[6] P. N. Moore, "Geology of the Nolin River District." Geol. Surv., Ky. Ser. 2, Vol. 2, pt. 2 (1877). See map.

The topographic map shows the existence of lakes in the lower courses of the valleys of Bullock Branch and the small hollow which heads just southeast of Watts School in western Edmonson County. Another lake of similar character which is not shown upon the map is located in the lower part of the valley of Crooked Creek. Four lakes of the same type occur in Butler and Warren Counties, nine miles west of the Edmonson County line, while still a dozen or more lie in the lower portions of tributaries of Green River further to the west.

Alluvial flats present along the course of Green River in Edmonson County are very narrow and the width of the valley bottoms between the slopes which rise steeply upon both sides is in a few places greater than a quarter of a mile. This condition prevails down stream to the mouth of Reedy Creek, four miles west of the Edmonson County line, at which point the valley begins to widen out and the river meanders upon an alluvial flat averaging one mile in width, which is bounded upon both sides by steep slopes.

The three features of the Green River Valley, which have been briefly described above, all suggest that this valley has been filled from the mouth of Honey Creek down stream to a greater and greater depth. An examination of the maps of the valley farther to the west reveals additional evidences of valley filling. The alluvial flats become much wider and are everywhere bounded by slopes, which, although not everywhere steep, rise abruptly. Swamps of several square miles in extent exist between Central City and Livermore and in the neighborhood of Providence. Island-like hills rise here and there above the alluvial flats which surround them upon all sides. Several excellent examples are to be seen in the Madisonville Quadrangle (Hopkins, McLean and Muhlenberg Counties), one of which, known as "The Island" is especially conspicuous. In several places also, the main drainage lines seem to have been somewhat modified. The valley fill evidently raised the valley floors to a height above the level of certain saddles on narrow ridges which intervened between two converging valleys and one of the streams left its original broad valley, flowed through one of these narrow gaps and entered the broad valley of the other stream some distance above their former junction. Such modification occurred

Topography, in black, enlarged from
U. S. G S. Mammoth Cave quadrangle

PLATE II.—THE MAMMOTH CAVE REGION AND A PART OF THE GREAT CAVERN

(SHOWN IN RED)

To accompany Kentucky Geological Survey
report, Vol. 28, on the geology of
Edmonson County, Ky., by J. M. Weller

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in the southeast corner of McLean County, where Green River originally flowed to the west in a great loop around the group of hills upon which the town of Island is situated, and joined Rough River three miles west of Livermore.

Another good example occurs in Daviess County six miles south of Owensboro, where the South Prong of Panther Creek formerly flowed to the south and west of Sutherland. A somewhat similar situation occurs in the northwestern part of Butler County except that here the original drainage has not been completely diverted into a new course. At this place Green River makes a large loop to the southeast, which is cut completely across at its base by Thorofare Creek. This stream occupies the lower portion of the valley of Slaty Creek, and then cuts across the low ridge which formerly separated Slaty Creek from Green River. Thorofare Creek is essentially a cut-off which carries a considerable part of the water of Green River during its flood stages.

The valley of Big Muddy River in southern Illinois possesses certain features which are similar to those in the Green River Valley of Kentucky just described. From a study of this southern Illinois river, Shaw[7] has shown that the Big Muddy Valley was occupied at two different times during the latter part of the glacial period by a lake. The ponding which produced these lakes was caused by the silting up of the valley of the Mississippi whose waters, derived from the melting glacial ice front, were heavily loaded with sediment. The filling up of its valley by the Mississippi proceeded rapidly and its tributaries which were not swollen with glacial water did not carry sufficient sediment to keep pace with this process. In consequence, the tributary valleys were dammed at their mouths and their waters were backed up and lakes were formed.

These lakes were slowly filled by sediment deposited both from the backwaters of the Mississippi and from the streams themselves whose lower courses had been flooded. After the recession of the ice sheet far to the north, the Mississippi received much less heavily sediment laden glacial waters and was

[7] E. W. Shaw, "Newly Discovered Beds of Extinct Lakes in Southern and Western Illinois and Adjacent States." Ill. State Geol. Surv. Bull. 20 (1915), pp. 139 ff. Also "Murphiesboro Herrin Folio." U. S. G. S. Geol. Atlas No. 185 (1912).

able to begin the process of clearing its valleys of the debris which chocked them. As the major stream cut into the alluvium in its valley and lowered its channel, the tributaries entrenched themselves in the lake beds which had accumulated in their lower courses and today the remnants of these deposits form terraces along the Mississippi tributaries.

The same general conditions which prevailed in the Mississippi Valley were also present during the later part of the glacial period in the Valley of the Ohio, and Shaw has called attention to the former existence of a lake in the Green River Valley.[8] While a second period of lake development followed the first in the Mississippi Valley, the results of only one such period have been recognized along the lower Ohio. These two main drainage basins also differ from each other in another respect. While the lakes developed along the Mississippi were apparently completely filled with sediment, the Ohio River began to clear its valley before the lakes present in the valleys of its tributaries had been completely silted up. After the Ohio had sufficiently cleared its valley and lowered its channel to effect the drainage of the lakes in its tributary valleys, the old lake basins appeared as somewhat concave flats which slope gently down from the farthest up stream projection of the former lakes, to some intermediate point and then rise in another gentle slope toward the Ohio.

The high water stage of the Ohio River at the time of its maximum valley fill corresponded approximately to the present level of between 420 and 440 feet above the sea. Terraces at this level are preserved at many places along the lower Ohio, and in Spencer County, Indiana, ten miles northwest of Owensboro, certain topographic features suggestive of beach ridges are present at this elevation partially blocking several small hollows. Veatch has called attention to these features but has not given them this interpretation.[9] Shaw has stated that similar features present in the extreme northwestern corner of Muhlenberg County, Kentucky, are beach ridges "beautifully developed and well preserved"[10] which exist at an elevation of something over 400 feet above sea level.

[8] E. W. Shaw, "Newly Discovered Beds of Extinct Lakes in Southern and Western Illinois and Adjacent States." Ill. State Geol. Bull. 20 (1915), Plate 14, opposite p. 148.

[9] A. C. Veatch: "Notes on the Ohio Valley in Southern Indiana." Jour. Geol., Vol. 6 (1898), pp. 257 ff.

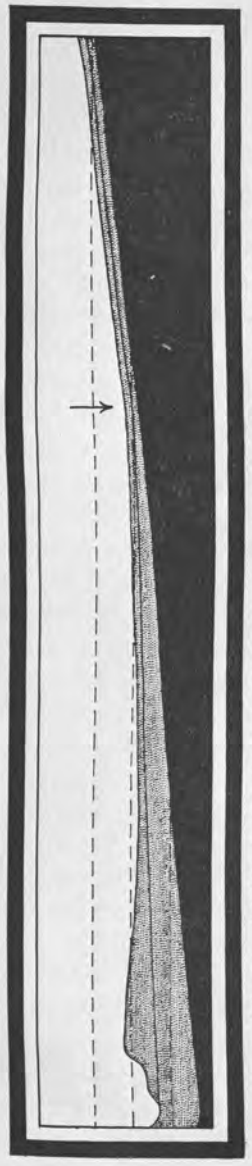

FIG. 27. RIVER TERRACE, NATURAL LEVEE, AND DEVELOPMENT OF LAKES.

The terraces adjacent to the Ohio River were originally developed as natural levees. They achieve their greatest elevation close to the Ohio and slope gently away from it with the result that the tributary streams are entrenched in their lower courses. This situation is clearly shown in the valley of Blackford Creek about 14 miles northeast of Owensboro. These natural levees in one case at least have produced important drainage modifications. Originally Panther Creek, undoubtedly, joined the Ohio in the vicinity of Owensboro, but the development of these natural levees dammed its course and it sought outlet by flowing westward along the edge of the hills and parallel to the levees to the Green River, which due to its greater volume had been enabled to cut through this barrier.

The lake, which during the late glacial time existed in the valley of the Green River and its tributaries, named by Shaw "Green Lake," reached its highest stage at an elevation corresponding to the present level of between 420 and 440 feet above the sea and extended up the Green River Valley into western Edmonson County. The abrupt change in the gradient of Green River which

[10] E. W. Shaw: "Newly Discovered Beds of Extinct Lakes in Southern and Western Illinois and Adjacent States." Ill. State Geol. Surv. Bull. 20 (1915), p. 147.

[11] Ibid: Plate 14.

occurs at the mouth of Honey Creek probably marks the eastern-most extension of this lake. Above this point the river flows in a channel which has probably been little modified since early Pleistocene times, while below the old channel has been silted up to a greater and greater depth. Wells driven in the flood plain of the Ohio River reveal old channels nearly 100 feet below the present one and it is probable that Green River at its mouth had also cut to this depth. If this figure is added to the present amount of fall in Green River between Honey Creek and the Ohio the resulting gradient is comparable to that which exists today to the east of Honey Creek.

The alluvial flats present upon either side of Green River at the mouth of Honey Creek lie at an elevation of between 420 and 440 feet, above sea level, and are consequently at a position identical with those which exist along the Ohio. To the east of Honey Creek the alluvial flats immediately rise to a degree consistent with the increased gradient of the river above this point.

The lakes present in the lower portions of some of the tributary hollows of Green River in western Edmonson County and the region farther to the west were produced by processes similar, though on a smaller scale, to those which resulted in the development of the lake in the valley of the Green River itself. The major stream, Green River in this case, as the result of its carrying a greater amount of sediment, silted up its valley at a rate with which its tributaries could not keep pace. Natural levees were formed across the mouths of the valleys which were thus dammed and lakes were formed, but before they were completely silted up the major stream began to clear up its valley and no longer overflowed during high water into the ponded valleys. These lakes owe their existence at the present time to the failure of the small streams which form their outlets to have as yet cut their channels to a sufficient depth in the alluvium to completely drain them.

CHAPTER V

STRATIGRAPHY—ROCKS NOT EXPOSED

General Remarks

The St. Louis Limestone is the oldest formation exposed within Edmonson County. In Allen County, which lies eight miles directly south of Edmonson, Silurian beds outcrop and the strata occurring between these and the St. Louis Limestone have been studied.[1] Still older beds belonging to the Ordovician and Silurian Systems are exposed in the Bluegrass Region of Kentucky[2] and in the Nashville District of Tennessee.[3] These formations are almost entirely limestone and shales. Sandstone is for the most part conspicuously absent, although some sandy limestones and shales do occur, and the St. Peter Sandstone, somewhat modified, is reported in a few wells.

Near Rhoda, in Edmonson County, a well has been drilled to a depth of over 3,000 feet in search of oil and in Warren County three or four miles north of Bowling Green a well has been drilled to a depth somewhat similar. Many shallower wells have been drilled in this portion of the state for the same purpose. When the nature of the beds penetrated is considered, it is not surprising to find that but little can be determined from a study of the logs. In most cases the driller has recorded nothing except the depth of the oil "sands" and the position of the "black shale." The black Chattanooga Shales is in fact the only horizon which can certainly be recognized in the logs and, consequently, it is adopted invariably as the datum for structural contour maps in Warren, Allen and Barren counties.

Well Logs

The log of the J. W. Cook Well No. 1, located southwest of Rhoda in Edmonson County and drilled early in 1916, has been furnished by Col. M. W. Crump[4] as follows:

[1] Shaw and Mather: "The Oil Fields of Allen County, Kentucky." U. S. G. S. Bull. 688 (1919).
[2] Miller, "Geology of Kentucky." Ky. Geol. Surv., Ser. 5, Bull. 2 (1919).
[3] Hays and Ulrich: "Columbia Folio.' U. S. G. S. Geol. Atlas No. 95 (1903).
[4] Shaw and Mather, "The Oil Fields of Allen County, Kentucky." U. S. G. S. Bull. 688 (1919), p. 37.

	Thickness	Depth
Surface material	20	20
Sand	15	35
Sand, yellow	50	85
Limestone, white	10	95
Shale, blue	20	115
Limestone, gray, water	15	130
Limestone, white	37	167
Limestone, blue	23	190
Limestone, white	8	198
"Slate," white	32	230
Limestone, white, cased (water at 242 and 298 feet; pulled casing and reamed)	95	325
Limestone, blue (Blue Lick water at 328 feet)	18	343
Limestone, white (fossils at 540 feet)	212	555
Limestone, gray	85	640
Limestone, sandy, gray (change at 760 feet; cased; change at 781 feet)	160	800
Limestone, blue (fossils at 864 feet)	154	954
Limestone	116	1070
Sand, white	137	1207
Shale, brown	35	1242
Shale and fossils	20	1262
"Slate"	28	1290
Limestone; show of oil	29	1319
Limestone, fossils (fine shells at 1405 feet)	86	1405
Shale, black (Chattanooga)	78	1483
Shale, fossiliferous	20	1503
Shale	32	1535
Limestone, brown	18	1553
"Slate;" shells	57	1610
Shale, pink	67	1677
Limestone, shells	6	1683
Shale, green	41	1724
Shale	79	1803
"Slate," fossiliferous	316	2119
Limestone ("Top of Trenton")	44	2163
Limestone, light, gritty	33	2196
Limestone, dark gray	33	2229
Limestone, light gray	15	2244
Limestone, dark	41	2285
Limestone, light and hard	187	2472
Limestone, soft	150	2622
Limestone, dark	243	2865
Limestone, black, brown and white	275	3140
Sandstone? ("Calciferous" or St. Peter?) water-bearing beds	2	3142

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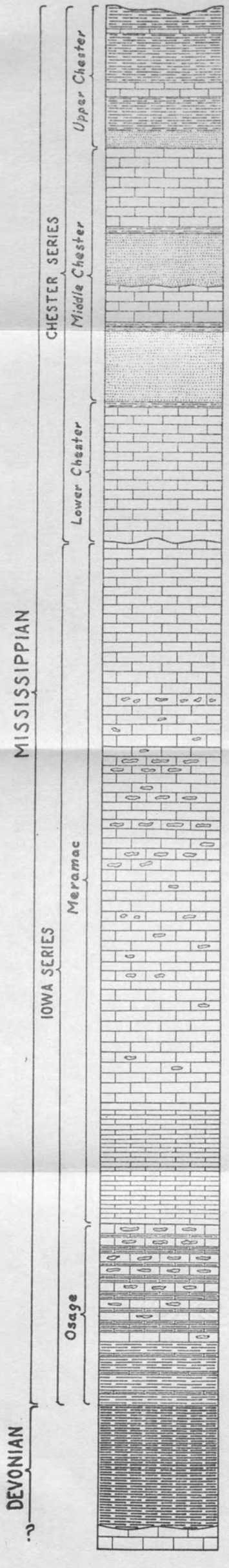
ren County
Green. It
ly 2000 feet

ess	Depth
	40
	40
	220
	220
	412
	418
	465
	498
	824
	899
	992
	1011
	1016
	1053
	1076
	1059
	1273
	1297
	1309
	1343
	1350
	1357
	1363
	1767
	1964
	2146
	2157
	2218
	2221
	2229
	2259
	2687
	2694
	2748
	2754
	2796
	2809



Leitchfield Formation 0′ to 125′
Greenish grey and variegated shales.
Tar Springs Sandstone locally developed at base. Massive limestone member 45′ above base. Yellowish impure limestone locally present 100′ above base.

Glen Dean Limestone 50′ to 70′
Rather massive evenly bedded grey crystalline limestone.
Richly fossiliferous bryozoan horizon near top.

Hardinsburg Sandstone 40′
Massive to shaly fine grained brown sandstone.

Unconformity
Golconda Limestone 40′
Massive crystalline grey limestone
Grey and carbonaceous shale and thin coal at base.

Cypress Sandstone 60′ to 75′
Massive brown sandstone.
Resistant to weathering.

Unconformity?
Renault-Paint Creek Limestone 100′ to 140′
Massive compact grey limestone with richly oolitic beds.
Productus horizon in upper part. Grey slate locally present at top.

Unconformity
Ste. Genevieve Limestone 150′ to 200′
Massive compact grey limestone, oolitic, rather unfossiliferous. Black chert occurs locally in lower part.

St. Louis Limestone 300′
Massive compact grey limestone in upper part with large rough fossiliferous cherts. Lower part contains earthy dolomites and black bituminous limestones.

Warsaw Limestone

Later Osage

Earlier Osage

Chattanooga Shale

Middle Devonian or
Silurian Limestone.

ROCKS EXPOSED IN EDMONSON COUNTY.

ROCKS NOT EXPOSED IN EDMONSON COUNTY.

FIG. 28. GENERALIZED SECTION OF THE MISSISSIPPIAN AND LOWER FORMATIONS OF EDMONSON COUNTY.

Surface material	
Sand	
Sand, yellow	
Limestone, white	
Shale, blue	
Limestone, gray, wate	
Limestone, white	
Limestone, blue	
Limestone, white	
"Slate," white	
Limestone, white, cas pulled casing and	
Limestone, blue (Blue	
Limestone, white (fos	
Limestone, gray	
Limestone, sandy, gra change at 781 feet	
Limestone, blue (foss	
Limestone	
Sand, white	
Shale, brown	
Shale and fossils	
"Slate"	
Limestone; show of o	
Limestone, fossils (fin	
Shale, black (Chattan	
Shale, fossiliferous	
Shale	
Limestone, brown	
"Slate;" shells	
Shale, pink	
Limestone, shells	
Shale, green	
Shale	
"Slate," fossiliferous	
Limestone ("Top of T	
Limestone, light, gritt	
Limestone, dark gray	
Limestone, light gray	
Limestone, dark	
Limestone, light and l	
Limestone, soft	
Limestone, dark	
Limestone, black, brov	
Sandstone? ("Calcifer ing beds	

This well started in the Hardinsburg Sandstone and the fact that the Golconda and Cypress cannot be recognized in the upper part of the log is evidence that the record was poorly kept.

The Lena Doyle Well No. 3 is located in Warren County three or three and one-half miles north of Bowling Green. It was drilled in September, 1923, and was carried nearly 2000 feet below the usual depth of wells in this vicinity.

Elevation above sea level 504 feet.	Thickness	Depth
Started on solid lime	40	40
Large flow fresh water		40
Lime, white and gray	180	220
White sulphur water		220
Blue and gray lime	192	412
Black sulphur water	6	418
Brown lime	47	465
Shallow sand (3 bbls. oil per day)	33	498
Blue and gray lime	326	824
Black shale	75	899
Black and gray lime	93	992
Deep sand (10 bbls. per day)	19	1011
Red rock	5	1016
Blue and gray lime	37	1053
Blue and gray lime	17	1076
Stray sand (no show)	6	1059
Blue and gray lime	181	1273
First Sunnybrook sand (no show)	24	1297
Gray and blue lime	12	1309
Second Sunnybrook sand (no show)	34	1343
Brown shale	7	1350
Broken gray lime	7	1357
Red rock	6	1363
Brown, blue and gray shale	404	1767
Hard gray and brown lime	197	1964
Tan colored lime	182	2146
Trenton sand (trace oil and gas)	11	2157
Gray lime	61	2218
Fine sandy lime (very hard)	3	2221
Gray lime	8	2229
Sandy lime, tan colored, hard	30	2259
Gray lime	426	2687
Fine sand (trace salt water)	7	2694
Brown and gray lime	54	2748
Tan colored sand (trace of sulphur)	6	2754
St. Peter sand, tan colored, hard	42	2796
Gray colored lime	13	2809

This well was started in the Ste. Genevieve Limestone about 190 feet below the base of the Cypress Sandstone.

Two deep wells have been drilled in Grayson County, at Anneta and Meredith, only a short distance north of the Edmonson County line. The well at Anneta, known as the J. E. McGrew No. 1, was drilled in 1916 and 1917. The log is as follows:[6]

	Thickness	Depth
Soil and clay	8	8
Sand rock	3	11
Gray shale	5	16
Black rock (asphalt)	1	17
Blue shale	70	87
Gray sand, trace of asphalt	40	127
Blue shale	28	155
Light gray shale	17	172
Blue shale	18	190
Lime and shale, water	10	200
White shale	5	205
Blue shale	30	250
Lime shells	5	255
Blue shale	48	303
Lime, white	8	311
Blue shale	15	326
Lime, gray and very hard	32	358
Shale	10	368
Sand	45	413
Lime, hard, Kaskaskia	35	448
Shale	8	456
Sand, lower 15 feet thin bands of sand and shale, Big Clifty	42	498
Shale, blue, soft	12	510
Lime, gray and moderately hard	5	515
Shale, gray hard	5	520
Lime, white hard	10	530
Shale, white hard	4	534
Lime, between 540 and 550 two soft streaks of lime, one about two feet thick and one about six inches, like thick white wash	40	574
Shale, tough hard white	10	584
Lime varying in color and hardness	156	740

[6] W. R. Jillson: "The Oil and Gas Resources of Kentucky." Ky. Geol. Surv., Ser. 5, Bull. 1 (1919), pp. 325-327.

	Thickness	Depth
Lime, gray sandy, with hard shells, probably Waverly, Blue Lick at 830	150	890
Lime, white soft, no grit	25	915
Lime, hard flinty gritty, cased at 918	7	922
Lime, brown and white soft	60	982
Lime, dark gray mixed with white, white part very soft	18	1000
Lime, brown and white	40	1040
Lime, dark gray hard	30	1070
Lime, dark brown hard	65	1135
Lime, black	9	1144
Lime, brown and gray shales	23	1167
Lime, gray	35	1202
Lime and shale mixed with shells occasionally	70	1272
Shale, sandy dark	3	1275
Shale, sandy light gray	15	1290
Lime, gray very hard, gas at 1355 about enough to burn three feet high out of casing, no change in rock	65	1355
Lime, black hard	45	1400
Lime, gray soft shelly	10	1410
Lime, gray and mixed with sand	5	1415
Lime, white sandy	70	1485
Shale, dove color, soft with hard shells of gray lime	35	1520
Gray sand and lime, show of oil at 1523, gas at 1531	19	1539
Shale, green and soft	17	1556
Shale, brown Devonian	110	1666
Lime, dark gray hard	25	1691
Lime, white and gray mixed	10	1701
Lime, dark brown	15	1716
Lime, gray	5	1721
Lime, light gray almost white, trace of oil, very hard	34	1755
Lime, brown, very hard	15	1770
Lime, gray soft white flaked	25	1795
Lime, white hard	35	1830
Lime, blue gray, trace of oil, little salt water	5	1835
Lime, white	25	1860
Sand, gray show of oil, stopped on hard shell, strong flow of salt water	5	1865
Sand, hard white	10	1875
Lime, gray mixed with shale	25	1900
Lime, brown moderately soft	10	1910
1100 feet of water in well		
Lime, brown	15	1925
Lime, gray very hard	5	1930

	Thickness	Depth
Lime, dark gray, trace of asphalt	5	1935
Lime, white hard	15	1950
Lime, gray and white	35	1985
Lime, gray shale and lime mixed	5	1990
Lime, dark gray changing to light gray	30	2020
Lime, blue gray	10	2030
Lime, light brown	55	2085
Shale, light gray	5	2090
Rock, light gray, shale or rock not determined	45	2135
Lime, gray	25	2160
Shale, blue gray	10	2170
Lime and gray shale in thin bed	15	2185

This well was started in the Pottsville and passed into the Mississippian either at the base of the 40 foot sandstone, at a depth of 127 feet, or else somewhere in the underlying shale beds. It penetrated through the whole of the Chester Series but the individual formations cannot be recognized in the log.

The log of the well at Meredith is as follows:[7]

	Thickness	Depth
Soil and clay	10	10
Gray shale	28	38
Gray sand	5	43
Black shale	32	75
Black sand, asphalt	5	80
Black shale	25	105
Sand	5	110
Black shale	40	150
Coal	1	151
Black shale	5	156
Gray sand	10	166
Black rock, asphalt	25	191
Shale	2	193
Gray sand	13	206
Gray shale	63	269
Brown lime	10	279
Gray shale	5	284
Red marl	16	300
Dark shale	6	306
Gray lime	10	316
Gray shale	4	320
Gray lime	46	366

[7] Ibid., p. 324.

	Thickness	Depth
Gray and white sand	46	412
Gray lime	33	445
Dark shale	5	450
Sand	60	510
Gray lime	92	602
White shale	3	605
White lime	25	630
Lime, sulphur water 774	300	930
Black sandy lime, gas show	10	940
Brown and white lime	55	995
Brown shale	10	1005
Brown and white lime	140	1145
Gray sandy lime, gas show	15	1160
Gray lime	35	1195
Gray shale	12	1207
Lime and shale	13	1220
Dark gray sand lime	25	1245
Dark shale	20	1265
Dark lime	155	1420
Gray sand	27	1447
Sand and shale	5	1452
Gray and white lime	123	1585
Light gray shale	13	1598
Black shale	120	1718
Black lime	20	1738
Black and white lime	5	1743
Gray lime	52	1795
Light brown lime	30	1825
Gray sandy lime, oil show	15	1840
Gray lime	10	1850
White lime	50	1900
Fine white sand, oil show and water	10	1910

This well started in the Pottsville and reached the Mississippian probably at the base of the 13 foot sand, at a depth of 206 feet. In this log the sequence of the Chester beds is well shown and the various formations are easily recognizable. The section is as follows:

	From	To
Lietchfield Formation	206	306
Glen Dean Limestone	306	366
Hardinsburg Sandstone	366	412
Golconda Limestone	412	450
Cypress Sandstone	450	510

Lower Mississippian and Devonian strata outcrop in Allen County and have been described by Shaw and Mather,[8] and the following account of the formations occurring beneath the St. Louis Limestone is taken largely from their description.

Devonian System

Onondaga Limestone. Limestone of Onondaga age, called "Corniferous" by Shaw and Mather, is exposed along Trammel Fork, Long Creek and Barren River in the eastern part of Allen County. Its thickness is not known but is undoubtedly variable, since in places the Chattanooga Shale rests directly upon the Silurian limestone. The greatest thickness observed was 56 feet on Barren River near Holland, where the base of the formation is not exposed. "Fossils are scarce and there is considerable variation in the lithologic character among the different exposures . . . The 'Corniferous' varies in color from bluish to brownish gray, but weathered surfaces near the outcrops are commonly nearly black. These surfaces display a coarse honeycomb of pitted appearance due to differential solution of the beds. Cavities and extensive caverns are numerous."

Chattanooga Shale. The Chattanooga Shale is exposed along Trammel Fork, Long Creek and Barren River in eastern and southern Allen County. Its thickness in this vicinity varies between 20 and 80 feet. Ten miles west of Bowling Green, the Willey well penetrated 152 feet of the black shale, while the well at Rhoda in Edmonson County reports a thickness of 78 feet. Generally this shale rests directly upon the uneven surface of the underlying limestones, although a bed of clay shale intervenes locally.

The Chattanooga Shale is "remarkably uniform in make up and is found in almost every well which penetrates to its horizon throughout the broad region of its occurrence, which covers thousands of square miles . . . " This formation is composed of very black fissel shale, which may be uniform in composition throughout its whole thickness but in certain regions it contains a few interbedded layers of green shale, wave marked

[8] Shaw and Mather: "The Oil Fields of Allen County, Kentucky." U. S. G. S. Bull. 688 (1919).

calcareous sandstone or dark coarsely crystalline richly bituminous limestone.

Mississippian System

Early Osage. Early Osage Shale, called New Providence by Shaw and Mather, is well exposed in Allen County along Walnut Creek north of Maynard, along Long Creek and Barren River northwest of Holland, and in the railroad cuts south of Petroleum. It exhibits a fairly constant thickness of 40 feet. The formation consists predominantly of shale and shaly limestone and is of a characteristic greyish green color. It is thin bedded, the calcareous strata seldom being more than ten inches thick although more massive layers do occur locally. Some of the limestone beds are composed almost entirely of stem plates of crinoids, some of which are of large size. One of the most characteristic features of the formation is its exceedingly cross bedded structure. A little chert occurs in a few beds within the formation, but it is not abundant. Geodes, however, are common at many places.

Later Osage. The Later Osage, referred to as the Fort Payne Chert by Shaw and Mather, is well exposed in Allen County on Walnut Creek north of Maynard, on Trammel Fork near the crossing of the Franklin Pike, and on both branches of Bays Fork near Scotsville, where the formation is approximately 100 feet thick. It overlies the New Providence Shale conformably, being separated from it by a transitional zone a few feet in thickness. The formation is composed largely of beds of pure, coarsely cystalline, pinkish gray limestone. "Some of these massive beds contain sheets of chert which increase in amount in the higher beds until at a horizon of 75 or 80 feet above the black shale the beds are characterized by numerous sheets three or four inches thick of light brown or milky white chert . . . " Geodes are less abundant in the lower part of this formation than they are in the underlying shales, but in the upper part they are numerous locally. Fossils are not as common in these beds as in either the overlying or underlying formations.

Warsaw Limestone. The Warsaw Limestone outcrops abundantly along Trammel and Bays Fork in central and western Allen County. It is composed of about 100 feet of limestones

and shales which apparently overlie the Osage conformably. The lower 20 feet of the Warsaw is composed mainly of shaly limestone, some of which is highly fossiliferous, with which are interbedded beds of coarsely crystalline gray limestone six inches or more in thickness. "The greater part of the formation, however, consists of bluish gray thin bedded cherty limestone containing many geodes . . . " While the color of the formation is dominantly gray or bluish gray thin beds of lemon yellow shale occur locally.

Spergen Limestone. Shaw and Mather are uncertain whether beds of Spergen age occur in Allen County or not. That portion of the section which might be referred to this formation consists of purer and heavier bedded limestone than the underlying Warsaw and has been included by them in the St. Louis Limestone Weller has recognized the Spergen Limestone in Caldwell County [9] where 40 or 50 feet occur beneath the St. Louis. Its total thickness, however, is not known as the base of the formation is not exposed. Butts reports the presence of 20 feet of Spergen Limestone in Jefferson County, but it dies out both to the west and south, and in the vicinity of Colesburg, in Hardin County, the St. Louis overlies the Warsaw upon an angular conformity. [10] From this data is seems probable that the Spergen Limestone may not be present in Edmonson County or the adjoining region.

Conclusions

A comparison of vertical distances between the base of the Cypress Sandstone and the top of the Chattanooga Shale in sections reconstructed from field measurements of the various formations and the well records which have been given above, produces some rather interesting results.

Shaw and Mather estimate that the Ste. Genevieve-St. Louis contact was reached at 45 feet in the Bowling Green well and, consequently, a thickness equivalent to the entire Renault-Paint Creek Limestone and the upper part of the Ste. Genevieve has been added to the depth of the black shale as recorded at this

[9] Stuart Weller: "Geology of the Princeton Quadrangle." Ky. Geol., Ser. 6, Vol. 10 (1923), p. 15.

[10] Charles Butts: "Mississippian Formations of Western Kentucky." Ky. Geol. Surv. (1917), p. 37.

	1	2	3	4	5
Formation	Measured Thickness	Bowling Green	Lena Doyle No. 1	Rhoda	Anneta	Meredith
Renault-Paint Creek	150	150	150	1275	1143	1088
Ste. Genevieve	200	155	40			
St. Louis	300					
Warsaw	100	670	824			
Later Osage	100					
Earlier Osage	50					
Total	900	975	1014	1275	1143	1088

place. The resulting 975 feet checks to within a reasonable degree with the measured thickness of the section.

The Lena Doyle well was started approximately 190 feet below the base of the Cypress and this amount has been added to the depth of the black shale at this locality. The resulting figure of 1014 feet checks closely with those obtained in a similar manner on numerous other wells situated in the same vicinity about four miles north of Bowling Green.

The Rhoda, Anneta, and Meredith wells penetrate the whole interval between the Cypress and the black shale. The variation in thickness of this interval between these not widely separated localities is of considerable interest. Due to the fact that the measured thicknesses of the three lower formations were obtained some 25 miles to the south of the nearest well considered above while those of the three upper ones were measured much closer at hand, it is probable that the greater part of the thickening of the section in numbers 1, 2 and 3 over the measured thickness is due to a thickening of the Osage and Warsaw in a northeasterly direction. This conclusion is in entire accordance with the much greater thickness of the Osage Group as developed upon the western flank of the Bluegrass Region.

The thinning of this interval, however, between Rhoda and Meredith cannot be explained upon this presumption. In this case the thinning may be due to a decrease in the thickness of the upper three formations of the section.

CHAPTER VI.

STRATIGRAPHY—ROCKS EXPOSED: MISSISSIPPIAN SYSTEM

General Remarks

The rocks exposed within Edmonson County are all of Carboniferous age, the section being as follows:

PENNSYLVANIAN	Pottsville Formation
MISSISSIPPIAN	
CHESTER SERIES	
UPPER CHESTER	Leitchfield Formation
MIDDLE CHESTER	Glen Dean Limestone Hardinsburg Sandstone Golconda Limestone Cypress Sandstone
LOWER CHESTER	Renault-Paint Creek Limestone
IOWA SERIES	
MERAMEC GROUP	Ste. Genevieve Limestone St. Louis Limestone

The Mississippian beds exposed within Edmonson County form a section about 800 feet thick which is composed of approximately 75% limestone, the remaining 25% being about equally divided between sandstone and shale. The limestones as a whole are somewhat similar in their lithological characteristics. For the purposes of description, two groups may be recognized, separated by the Cypress Sandstone. The lower limestone group includes the St. Louis, the Ste. Genevieve and the Renault-Paint Creek formations. These limestones form a continuous series of beds with somewhat similar lithologic characters, especially the two upper members of the series. Paleontology supplies the most reliable criteria for differentiating them and in many places, where exposures are poor and the talus covering is thick, it is difficult or entirely impossible to establish the position of the precise contacts between them. These three limestones together have been referred to as the Mammoth Cave Series, in some of the older reports of the Kentucky Survey. The upper limestone group includes the Golconda and Glen Dean

which are separated by the Hardinsburg Sandstone. In most sections these formations can be readily distinguished by their position with regard to the intervening and underlying sandstones, although they are much alike lithologically.

The formations of the Chester Series, as developed in Edmonson County, exhibit some important differences from the equivalent formations in Caldwell, Crittenden and Livingston counties, Kentucky,[1] which is the nearest area where they have been studied and mapped in detail. In these western Kentucky counties the complete section is present, as worked out by Weller in southern Illinois,[2] with the exception only of the Aux Vases

	EDMONSON COUNTY SECTION	SOUTHERN ILLINOIS SECTION
UPPER CHESTER	Leitchfield Formation	Kinkaid Limestone Degonia Sandstone Clore Limestone Palestine Sandstone Menard Limestone Waltersburg Sandstone Vienna Limestone Tar Springs Sandstone
MIDDLE CHESTER	Glen Dean Limestone Hardinsburg Sandstone Golconda Limestone Cypress Sandstone	Glen Dean Limestone Hardinsburg Sandstone Golconda Limestone Cypress Sandstone
LOWER CHESTER	Renault-Paint Creek Limestone.	Paint Creek Limestone Bethel Sandstone Renault Limestone Aux Vases Sandstone
	Ste. Genevieve Limestone	

Sandstone at the base. In Edmonson County, not only is the Aux Vases lacking but the Bethel Sandstone as well. Here the

[1] Stuart Weller: "Geology of the Princeton Quadrangle." Ky. Geol. Surv., Series 6, Vol. 10 (1923).

[2] Stuart Weller: "The Chester Series In Illinois." Jour. Geol., Vol. 28, Nos. 4 and 5 (1920).

Renault Limestone is overlain in seemingly conformable sequence by the Paint Creek beds, with no line of demarcation capable of being followed and mapped. The Upper Chester Group also, as developed in these two Kentucky regions is diverse in character. The eight separate and sharply defined Upper Chester formations of western Kentucky are represented in Edmonson County by a single exceedingly variable series of shales with occasional limestone and sandstone lenses, here referred to as the Leitchfield Formation. The Chester section of Edmonson County is compared in the foregoing table to the complete succession in Southern Illinois, the Middle Chester Group alone being typically developed in both regions.

St. Louis Limestone

Name. The St. Louis Limestone was first named by Englemann from the city of St. Louis which is its type locality.[3]

Distribution. The St. Louis Limestone in Edmonson County is confined to the extreme southeast corner, where it outcrops over an area of 13 or 14 square miles. It extends from the county line on the south and east to a line roughly coinciding with the Dixie Highway, north of which it passes beneath the overlying Ste. Genevieve.

Thickness. The entire thickness of the St. Louis Limestone is not exposed within the county and nowhere in the immediately adjoining region are the exposures suitable for its measurement. Although many oil wells in the field around Bowling Green have passed through the entire formation, its upper and lower limits have not been recognized on account of the continuous limestone succession. Some of these wells, however, which start near the St. Louis-Ste. Genevieve contact reach the Chattanooga Shale at a depth such that the thickness of the St. Louis cannot be far from 300 feet. This figure is somewhat less than might be expected considering estimates made both to the west and to the northeast. Weller reports the exposure of 200 feet of beds referable to this formation in the southwest corner of the Princeton, Kentucky, Quadrangle and the presence of from 300 to 400 feet of St. Louis in the deep well at Cedar Hill in the same quad-

[3] G. Englemann: "Remarks on the St. Louis Limestone." Am. Jour. Sci., Ser. 2, Vol. 3 (1847), pp. 119-120.

rangle,[4] and Butts reports a thickness of 500 feet of St. Louis along the Louisville and Nashville Railroad between Colesberg and Tunnel Hill.[5]

FIG. 29. LIMESTONE CLIFFS UPON THE EASTERN SIDE OF CEDAR SINK.

The line of division between the Ste. Genevieve below and the Renault-Paint Creek above occurs somewhere within these exposures.

Topography. The extent of the St. Louis Limestone in southeastern Edmonson County can be discerned easily upon the topographic map on account of the presence of numerous small sink holes which are highly characteristic of the upper part of this formation. In this area there is no surface drainage, all of the rainfall being carried off through underground channels which connect with these sink holes in all directions.

The topography of the lower St. Louis beds presents a strong contrast to that described above. Sink holes are rare. Drainage has developed along normal lines, but the steep sides of the valleys and the flat topped divides indicate that it has not yet reached a fully mature condition. These streams, of which Gardner Creek is an example, flow down the dip of the beds and disappear in sink holes as soon as the more soluble upper St. Louis beds are reached. Only a small area of this type of

[4] Stuart Weller: "Geology of the Princeton Quadrangle." Ky. Geol. Surv., Series 6, Vol. 10 (1923), p. 19.

[5] Charles Butts: "Mississippian Formations of Western Kentucky." Ky. Geol. Surv. (1917), p. 40.

topography, however, is present in the extreme southeast corner of the county.

Lithologic Character. The St. Louis Limestone is not extensively exposed anywhere within Edmonson County. Small outcrops are fairly common, but in general the formation is covered by a heavy blanket of residuum which probably reaches a thickness of over 20 feet in many places. All of the outcrops of the St. Louis consist of limestone and if any shale is present within the formation it is not exposed. The limestone of the upper and lower parts of the St. Louis are as different as the topography which develops on the surface of these respective portions. The upper part consists largely of grey limestone ranging in all degrees from a dense to a coarsely crystalline texture, although finely crystalline is the rule. The beds are hard and compact and some of them contain an abundance of minute scattered transparent quartz grains. Thin buff colored beds with lithographic texture occur locally. Well preserved fossils are rare, although some of the more crystalline beds contain numerous crinoid and echinoid plates, but these are seldom apparent upon freshly broken surfaces, their presence generally being noted only upon weathered ledges which have been recently exposed from beneath the soil. These upper beds weather into rounded surfaces. Irregular beds of greyish chert occur in the limestone at some localities but they are by no means common in the exposures. No true oolite has been observed in the St. Louis Limestone in this district, this being one of the lithologic criteria for distinguishing it from the overlying Ste. Genevieve.

The residual clay developed from the upper St. Louis beds is of deep red color and contains weathered chert fragments in great abundance. These cherts, or "burrstones," as they are locally called, are angular, often tabular, in shape and may attain dimensions as great as two feet in length by eight inches in thickness. They are more or less porous and stained brown or red with iron oxide, this color sometimes not extending beyond the surface. Many of the cherts contain casts of fossils and in some of them they are present in great abundance. It is from these residual chert fragments that the best fauna of the St. Louis may be obtained.

In the middle part of the St. Louis Limestone there occur a few very fine grained to dense beds which exhibit a peculiar banded appearance. These beds are composed of fine but continuous layers in various shades of grey and light buff. The

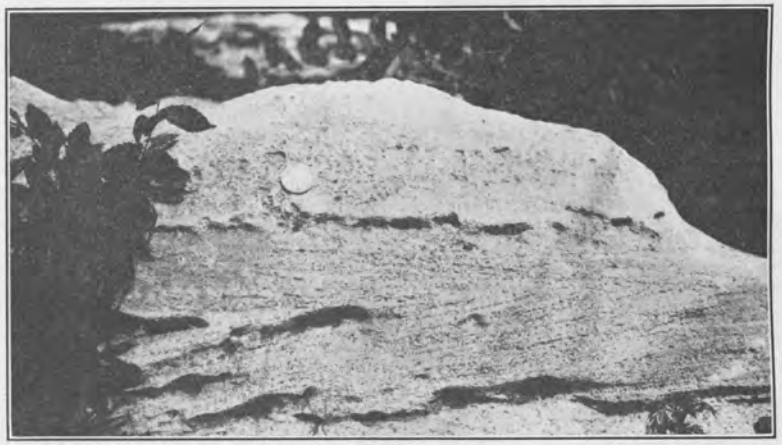


FIG. 30. CROSS BEDDING IN THE STE. GENEVIEVE LIMESTONE.
This outcrop occurs in the Reservoir Park, Bowling Green, and is an example of the structure which is not uncommon in the upper part of this formation.

bands are not in the nature of shaly partings, as the composition and texture seem to be uniform and the rock breaks no more easily along the banding than it does transversely to it.

The lower part of the St. Louis Limestone is composed of beds ranging from light grey to black in color. The black limestones are highly characteristic and may be extremely hard and dense with a finely crystalline texture. Some of these beds smell strongly of petroleum upon freshly broken surfaces, as at an outcrop located by the roadside one-quarter mile north of the county line and one-quarter mile west of Gardner Creek. Interbedded with black limestone there occur some fine grained, sandy appearing light grey or buff dolomitic beds which are sparsely fossiliferous locally.

The residual clay overlying the lower St. Louis beds is similar to that associated with the higer beds, but in addition to the large angular cherts of the upper St. Louis it contained scattered subspherical cherts ranging up to four inches in diameter. These

cherts are brown in color and of a porous rotten texture and contain no fossils. Some of them are solid but others possess central cavities which are commonly filled with a fine siliceous powder.

Stratigraphic Relations. The lower boundary of the St. Louis Limestone is not exposed in Edmonson County. The exact line of separation between the St. Louis and Ste. Genevieve Limestones has nowhere been observed in Edmonson County or adjacent parts of Kentucky. In this region there was probably no break between the two formations as conformability is the relation which has been observed generally throughout the Ohio Valley.[6]

Correlation. The St. Louis is known as a persistent formation of rather uniform lithologic character throughout the Mississippi and Ohio Valleys from Iowa to Alabama. The corals *Lithostrotion canadense* and *L. proliferum* are its most characteristic index fossils. The Lithostrotion and Barren Limestone of D. D. Owen (1856 and 1859), the Cavernous Limestone of Lyon (1860), the Middle or Lawrence-Crawford Limestone of R. Owen (1862), the Mitchell Limestone of Siebenthal and the Mammoth Cave Limestone of Miller are all to be correlated in whole or in part with the St. Louis.

Paleontology. Although fossils are more or less abundant in certain layers of the St. Louis Limestone the dense and compact nature of the rock makes the collection of identifiable forms exceedingly difficult. A patrial list of the fossils observed in the residual chert from the upper part of the formation is given below.

UPPER ST. LOUIS FAUNA FROM RESIDUAL CHERT

Triplophyllum sp.
Lithostrotion canadense (Castel)
L. proliferum Hall
Syringopora sp.
Platycrinus cf. *penicillus* M. & W.
Archaeocidaris sp.
Stenopora sp.
Fenestella (several spec.)
Polypora (several spec.)

[6] Stuart Weller: "Geology of the Princeton Quadrangle." Ky. Geol. Surv., Ser. 6, Vol. 10 (1923), p. 19.

Rhombopora sp.
Cystodictya lineata Ulrich
Dichotrypa sp.
Orthotetes cf. *keokuk* (Hall)
Productus marginicinctus Prout
P. *ovatus* Hall
P. *scitulus* M. & W.
Dielasma sinuatum Weller
Spiriferina sp.
Spirifer cf. *pellaensis* Weller
Reticularia cf. *setigera* (Hall)
Cliothyridina sp.
Composita trinuclea (Hall)
Myalina sancti-ludovici Worthen
Schizodus sp.
Aviculopecten (2 spec.)
Straparollus sp.
Naticopsis sp.

The following forms were collected from lower St. Louis beds one and three-quarters miles east of Rocky Hill by the side of the road which crosses Gardner Creek, one-quarter mile north of the county line.

LOWER ST. LOUIS FAUNA ONE AND THREE-QUARTER MILES EAST OF ROCKY HILL

Archaeocidaris (plates and spines)
Fenestella (several spec.)
Schellwienella sp.
Schuckertella sp.
Dielasma sp.
Brachythyris altonensis Weller
Eumetria verneuiliana (Hall)
Bellerophon sp.

Ste. Genevieve Limestone

Name. The Ste. Genevieve Limestone was named by Shumard [7] from exposures which occur along the Mississippi River bluffs just south of Ste. Genevieve, Missouri.

Distribution. In Edmonson County this formation outcrops in a narrow belt between the St. Louis on the south and the line of Cypress crowned hills to the north. An extension from this belt projects into the double pronged valley southwest of Cedar Hill School. It outcrops continuously along both sides of Green River and extends up into the tributary valleys from the mouth of Buffalo Creek to the east county line. The Ste. Genevieve is also extensively exposed in the bottoms of the large valley sinks in the southeastern parts of the county, such as Cedar Sink. Cedar Spring and Woolsie Hollows and Houchins Valley.

[7] B. R. Shumard: "Observations on the County of Ste. Genevieve." St. Louis Acad. Sci. Trans., Vol. 1 (1859), p. 406.

Thickness. At no locality within Edmonson County is it possible to accurately measure the thickness of the Ste. Genevieve Limestone. The whole of this formation is, however, exposed in Pilot Knob which lies in Warren County three miles southeast of Rocky Hill. Here it is not possible to locate the upper and lower boundaries with entire accuracy, but a careful examination shows that the formation attains a thickness of about 180 feet.

Topography. The Ste. Genevieve Limestone is not a formation greatly resistant to weathering. It characteristically occurs upon the hillsides, but where it does form the lower and more level land surfaces, as in the narrow belt north of the outcrop of the St. Louis and in the bottoms of the valley sinks, numerous sink holes have developed within it. However, these sink holes generally are larger, less steep-sided, and consequently fewer than those which occur within the St. Louis area.

Lithologic Character. Ste. Genevieve is composed almost entirely of limestone. In Warren County, north of Bowling Green, a few light colored shale beds two feet or more in thickness were observed in the middle of the formation. In Edmonson County, however, no true shales were anywhere encountered but in the higher part of the formation there are noticeable persistent shaly partings of a chalky color separating some of the more massive beds. Such partings are well displayed in Cedar Sink.

The color of the limestone varies from nearly white or light grey to bluish, and there are a few thin buff-colored beds of lithographic texture. Much of the Ste. Genevieve is finely crystalline to dense limestone containing oolites which are not noticeable except upon close inspection. The oolites, however, occur in all proportions from a few scattered grains to the almost exclusive constituent of the rock. In general the oolitic char-

acter of the Ste. Genevieve becomes more conspicuous in passing from the lower to the upper part. Beds two or three feet in thickness, composed almost entirely of oolites do occur, however, close to the base of the formation. Such beds are valuable markers, as in general field practice the lower boundary of the Ste. Genevieve is drawn below the lowest observed oolite. Rounded fragments of various types of fossils, which bear every evidence of having been worn by wave action, are associated commonly with the oolites in the more conspicuously oolitic beds. Much of the Ste. Genevieve evidently was deposited in shallow water. This conclusion is corroborated by the crossbedding which is a common feature of some granular and oolitic beds, particularly in the upper part of the formation. This crossbedding usually is to be observed only upon the sides of ledges which have been exposed to prolonged weathering.

The Rosiclare Sandstone member, which occurs in the midst of the Ste. Genevieve in southeastern Illinois and western Kentucky, is not present in Edmonson County or its vicinity. This sandstone is evidently the result of condition operating locally and which did not affect the region of Edmonson County.

The Ste. Genevieve is not a highly fossiliferous formation and most of the beds are essentially barren of recognizable forms. The richly oolitic beds are a particularly poor hunting ground for the paleontologist. Many of the beds of the formation carry plates of *Platicrinus penicillus* and a species of echinoid, but these usually are to be observed upon favorably weathered surfaces only.

The Ste. Genevieve is a chert bearing formation. The cherts develop as irregular tabular masses up to two inches in thickness. They are of a dark bluish grey or black color, and weather white, and are most conspicuously developed in the lower portion of the formation. While the cherts are a common constituent of the residuum, they have not been widely observed in situ. They are well exhibited, however, in their original position on the north side of Green River just above Dennison Ferry at the east line of Edmonson County.

The Ste. Genevieve weathers characteristically into rounded surface which project above the soil of the hillsides. These surfaces, when present in the open and subjected to the full

force of the sun, became bleached to a chalky color. This bleaching affects only the surface of the rock, the interior retaining its original grey color. Exposures of the limestone which occur in the woods, protected from the direct sunlight, are of a grey color closely simulating the original hue of the rock.

Residual material derived from the weathering of the Ste. Genevieve Limestone is composed of fine iron-stained clay with an admixture of chert fragments. The color of the residual clay varies from a deep rusty brown to brilliant red and is a most conspicuous feature of the limestone areas. The residual cherts are of two types. The tabular cherts, already described, break up and are present in small angular fragments which are by no means as large or as rough as those so characteristic of the upper part of the St. Louis. They are usually weathered to such an extent that the original dark color has been entirely destroyed and they become stained brown with iron. A second type of chert has been produced by the complete silification of certain beds of the Ste. Genevieve. These cherts preserve the original structure of the limetsone which has been replaced and some of them show the oolitic texture in great detail.

Stratigraphic Relations. The Ste. Genevieve Limestone succeeds the St. Louis conformably. Although this contact has not been observed in Edmonson County this is the relation which the two formations uniformly bear to each other throughout the Ohio Valley. In the field, considerable difficulty is experienced in mapping this contact since the critical exposures are few and not extensive. The boundary as drawn on the map accompanying this report has been determined largely from the southward extension of the oolitic beds and the northward extension of the characteristic, large and rough residual cherts of the upper St. Louis.

The exact contact between the Ste. Genevieve and the Renault has not been observed in Edmonson County, this portion of the section being covered uniformly by talus accumulations. An unconformity, doubtless, separates them, as the most important break in the Mississippian System occurs at this horizon throughout the region to the west, where these formations have been carefully studied.

Correlation. The Ste. Genevieve Limestone is widely distributed throughout the Mississippi and Ohio Valleys, from Iowa, where it is known as the Pella Beds, across Illinois, Indiana and Kentucky and as far south as Alabama. The greater part of the Ste. Genevieve, as determined by Ulrich in Kentucky, is to be correlated with the original Ste. Genevieve of Missouri, but the upper division of his Ohara member is now known to be separated from the remainder by an unconformity, these upper beds with their characteristic Chester fauna being assigned to the Renault. The Mitchell Limestone of Indiana and the Mammoth Cave Limestone of Kentucky are both to be referred in part to the Ste. Genevieve.

Paleontology. The Ste. Genevieve Limestone of Edmonson County has yielded no extensive fauna. In most of the beds, good fossils are extremely rare. *Platycrinus penicillus* is a characteristic fossil of this formation. Its stem plates are easily recognized by their oval outlines and marginal spines. These plates may not be present in all the beds of the formation, but wherever exposures are at all extensive, careful search will reveal them, anywhere from the top to the bottom of the formation. This species does not occur above the Ste. Genevieve, nor is it definitely known from the St. Louis in this district, although stem plates of similar appearance but larger size are common in the latter formation.

The only other fossils which are at all common in the Ste. Genevieve are corals. *Syringopora* occurs in the lower portion of the formation and *Lithostration harmodites* is abundant in a fairly well defined zone near the top of the formation. In those regions farther to the west where the Rosiclare Sandstone member is present, *L. harmodites* is a characteristic fossil of a portion of the beds which occur above this member.

Renault-Paint Creek Limestones

Name. The Renault and Paint Creek Limestones were named by Weller[8] from exposures in Renault Township and along Paint Creek in Monroe County, Illinois. From these localities the two formations have been recognized and mapped in

[8] Stuart Weller: "Stratigraphy of the Chester Group in Southwestern Illinois." Ill. Acad. Sci. Trans., Vol. 6 (1914), p. 125.

detail, continuously to Princeton, Kentucky. In Edmonson County the Bethel Sandstone which separates these two formations farther to the west is not present nor has there been detected any interruption in the sequence of limestone beds which might represent the Bethel Sandstone interval. Continuous limestone sedimentation prevailed from the beginning of Renault to the end of Paint Creek time and because of the lack of any lithological or paleontological means of differentiating these formations, they have been mapped and will be considered in this report as a single unit.

Distribution. In the southeastern corner of Edmonson County the Renault-Paint Creek Limestone outcrops upon the hillsides as a narrow band above the Ste. Genevieve. It occurs along both sides of Green River, extending back into the tributary hollows from near the mouth of Nolin River to the east county line. North of Green River, isolated patches of the limestone are exposed near the mouths of First and Second Creeks and in the lower part of Bylew Creek. South of Green River it is extensively exposed in all of the valley sinks from Double Sink to Houchins Valley. In the case of Cedar Spring Hollow, the Green River exposures are connected with those of the Dripping Spring Escarpment in the southeast corner of the county. Isolated patches of the Renault-Paint Creek occur in the lower part of Alexander Creek, in the central part of the Beaverdam Creek and in a number of sink holes such as those south and southeast of Little Hope School and southeast of Liberty.

Thickness. The thickness of the Renault-Paint Creek Limestone varies considerably. Three or four miles west of Bowling Green there are 200 feet of limestone between the Ste. Genevieve and the Cypress. In Edmonson County the greatest observed thickness is less than this, while about 120 feet is the measure of its usual development. The following are detailed figures on the thickness of the Renault-Paint Creek at a number of localities.

LOCALITY	Thickness
4½ miles north-northwest of Bowling Green	80 feet
Edmonson County line 2¼ miles northwest of Glasgow Junction	100 feet
West side of Green River 4/5 miles northwest of Mammoth Cave	130 feet

West side of Chicken Hollow	110 feet
½ mile northeast of Dripping Springs School	100 feet
East side of Green River at Great Onyx Cave	120 feet
North of Hunt's Sink	115 feet
South side of Green River at Doyle's Ford	130 feet

Topography. The topography developed upon the Renault-Paint Creek Limestone is essentially similar to that of the Ste. Genevieve. This formation characteristically forms steep hill sides such as those of the Dripping Spring Escarpment and the slopes along Green River in the eastern part of the county. Where somewhat more level surfaces are developed upon this formation as in the bottom of some of the valley sinks, these are pitted with sink holes similar to those which occur under like circumstances in Ste. Genevieve.

Lithologic Character. In Lithologic character the Renault-Paint Creek Limestone is closely similar to the upper portion of the Ste. Genevieve and these two formations can be separated, with certainty, only by paleontologic means. The beds are in general of a light gray color and range in texture from dense to coarsely crystalline. Oolitic beds are conspicuous and on the whole the Renault-Paint Creek is probably more oolitic than the upper part of the Ste. Genevieve. The oolites may occur scattered through a crystalline ground mass or by increasing amounts come to be the chief constituent of the rock. It is from beds of this type in the Renault-Paint Creek formation, which may attain thicknesses of 20 or more feet, that the locally famous "Bowling Green" building stone is quarried in Warren County. These highly oolitic beds are commonly of a lighter color than the crystalline strata, although in places they are stained by impurities to gray or buff. Some of the oolitic beds of the Renault-Paint Creek exhibit more perfect crossbedding than any which is to be seen in the Ste. Genevieve, but this cross-bedded structure is apparent only in ledges which have been exposed to considerable weathering.

The Renault-Paint Creek Limestone weathers to rounded surfaces separated by deep solution channels in the limestone. Those outcrops which are exposed to the strong sunlight become bleached and assume a chalky white color similar in appearance to beds of the Ste. Genevieve limestone exposed under like conditions. This bleaching action affects only the surface of the outcrops, the interior of the rock retaining its original grey color.

The Renault-Paint Creek Limestone is nearly free from chert, but it contains numerous peculiar, outward growing spherical clusters of quartz crystals commonly two inches or less in diameter. These quartz clusters are not often observed in situ but they are a highly characteristic element of the Renault-Paint Creek residuum. They are usually somewhat irregular in outline, but many of them are of a nearly perfect spherical form. They have grown outward from some small nucleus, possibly a sand grain. The interior portions consist of small concentrically banded spheres of cryptocrystalline quartz about the size of a pea or larger. From these have grown outward in every direction quartz crystals, which may attain a maximum length of about one inch. Growth has apparently been accomplished by the addition of silica upon the pyramidal faces of these crystals which are crowded tightly together, no new crystals being introduced. When these clusters are broken, the individual crystals are seen to possess one perfect pyramidal termination, the remainder being a much more accute pyramid, the surfaces of which were determined by the form of the adjoining crystals. The more nearly spherical clusters when broken in two resemble a flower of the daisy type, the central siliceous ball forming the heart of the flower and the radiating quartz crystals taking the place of the petals. These clusters occur in vugs entirely surrounded by calcite and also directly in the limestone itself. Their growth can have been accomplished in no other manner than by the replacement of the limestone or calcite by quartz.

No important shale members have been observed in the Renault-Paint Creek formation except at the very top. Exposures of the exact contact between the Renault-Paint Creek Limestone and overlying Cypress Sandstone are rare, this horizon commonly being hidden by slumped blocks of sandstone. Shale has been observed at the contact at only two localities, while at many other places the sandstone lies directly upon the limestone. In Warren County one mile south of Penn Chapel School and two miles from the Edmonson County line, a foot of dark grey shale is present at the very top of the Renault-Paint Creek. In Edmonson County one-third of a mile southwest of

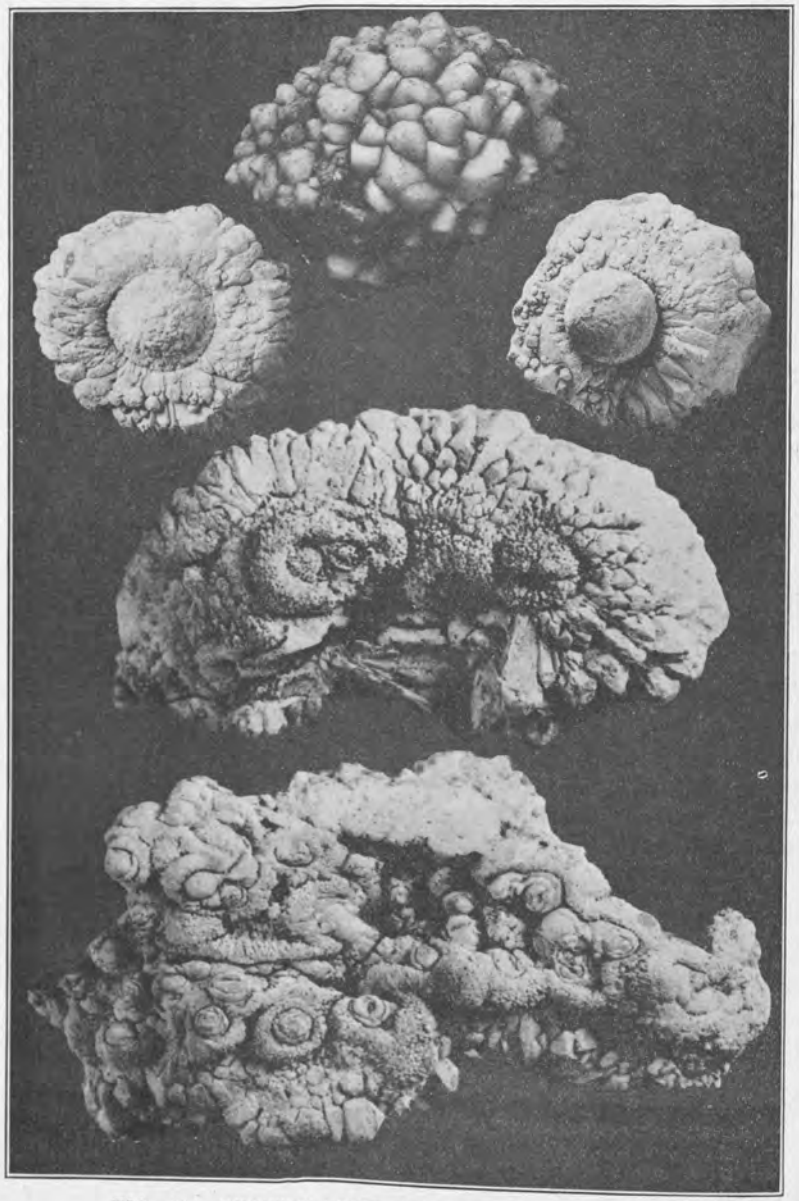


FIG. 31. CRYSTALLINE QUARTZ CONCRETIONS.
These typical specimens are from the Renault-Paint Creek Limestone showing the exterior and interior character of both simple and compound clusters.

McCoy Landing on Green River, about 15 feet of shale occupies the same position. The shale ranges in color from buff through light to dark grey, and one or two thin limestone ledges are interbedded in its lower part. Some of the lighter colored shale is slightly sandy and true shale partings are not well developed within such beds, the material generally "tearing" apart and producing rough hackly surfaces. At this locality one thin layer of light grey color contains numerous clusters of well formed pyrite crystals varying in size up to one-half inch in diameter.

The Renault-Paint Creek is not a highly fossiliferous formation. *Talarocrinus* occurs throughout and a careful search will reveal this crinoid at almost any locality where the beds are extensively exposed. *Pentremites* occur rather abundantly in certain layers. The oolitic beds are nearly barren of well preserved fossils although more or less worn fragments are intimately associated with the oolites. The most fossiliferous horizon occurs near the top of the formation and is characterized by abundant specimens of *Productus*. In Warren County north of Bowling Green this horizon is composed of thin bedded and somewhat shaley limestone which weathers to a rather yellowish color, of which small slabs studded with fossils are often seen. In Edmonson Couty the *Productus* layer losses its thin bedded charac ter and assumes a massive structure more in harmony with the remainder of the formation, but productids, together with a scattering of other forms, are abundant at many localities.

The residual clay resulting from the weathering of the Renault-Paint Creek Limestone is similar to that which occurs overlying the Ste. Genevieve. It is of a fine close texture and ranges in color from reddish rusty brown to brilliant red. This clay is largely free from chert but contains numerous clusters of quartz crystals of the sort which have been described. Careful search at some localities also reveals numerous tiny quartz crystals, the largest observed measuring 16 mm. in length. These crystals when unbroken are very perfect in form with terminations at both ends and show no evidence of attachment at any point. They are probably developed in the limestone by the process of replacement.

Stratigraphic Relations. The Renault-Paint Creek Limestone is separated from Ste. Genevieve by an unconformity of considerable importance which, although it has not been observed in Edmonson County, has been encountered at many places farther to the west. In southwestern Illinois and the adjoining portion of Missouri these two limestones are separated by the Aux Vases Sandstone 75 to 80 feet in thickness, which lies unconformably upon the Ste. Genevieve. This unconformity is erosional in character as is shown by the basal conglomerates and the fact that in one place the Aux Vases rests upon the St. Louis,[9] the entire Ste. Genevieve and a portion of the St. Louis having been removed prior to the initial period of Chester sedimentation.

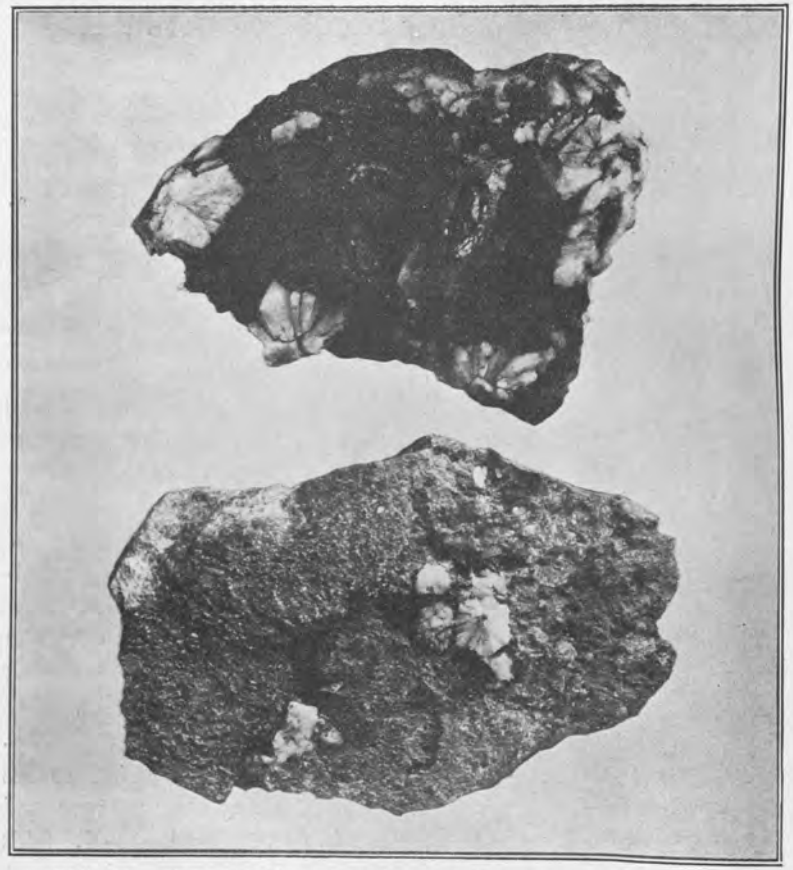


FIG. 32. CRYSTALLINE QUARTZ CONCRETIONS IN MATRIX.

The concretions of the upper specimen are surrounded by coarsely crystalline calcite which shows almost black in the illustration while in the lower they are embedded in fine grained grey limestone.

In Edmonson County and the adjoining portion of Warren County the Renault-Paint Creek varies considerably in thickness, this variation probably being due to relief developed upon the Ste. Genevieve by erosion during the interval of emergence which preceded the Chester sedimentation.

The relation which exists between the Renault-Paint Creek Limestone and the overlying Cypress Sandstone in Edmonson County is not altogether clear. At most places where this contact has been studied, the sandstone rests directly upon the limestone with no transitional beds of shaly nature. It is rather improbable that the conditions of sedimentation changed abruptly from those which produced massive limestone to those under which equally massive sandstone was deposited, so that this relation points toward the existence of an unconformity at this horizon, but it could not have been a very important break for there is preserved in at least two localities shale which definitely belongs with the underlying limestone.

Correlation. The Renault and Paint Creek Limestones are known as separate and distinct formation from St. Clair County, Illinois, to Ste. Genevieve County, Missouri, and thence completely across the State of Illinois to Hardin County. They continue beyond the Ohio River into Kentucky, completely encircle the Western Coal Field and extend back in a northwest direction into Indiana. Somewhere along the southern side of the Western Kentucky Coal Field, the Bethel Sandstone which separates these two formations, at least as far as Princeton, Kentucky, disappears and no stratigraphic means for separating them remain. To the northeast, however, in Breckenridge County, the Bethel Sandstone is again present where it has been mistakenly called the Sample Sandstone.[10]

The Renault-Paint Creek Limestone of Edmonson County is equivalent to Ulrich's Upper Ohara of the Ste. Genevieve com-

[9] Stuart Weller: "The Chester Series in Illinois." Jour. Geol., Vol. 28 (1920), pp. 287, 288.

[10] Charles Butts: "Mississippian Formations of Western Kentucky." Ky. Geol. Surv. (1917), p. 70.

bined with the limestone for which he proposed the name Tribune. It is also the limestone to which Butts and Ulrich have applied the name Gasper, and it has been included by Miller wtih the Ste. Genevieve and St. Louis Limestones below, in the so-called Mammoth Cave Limestone.

The Bethel Sandstone parting in this Lower Chester series of limestones is well developed to the west of the western Kentucky coal fields. It must continue eastward, deeply buried beneath the higher Chester beds and the overlying Pennsylvanian sediments, for it reappears east of the coal fields in Breckinridge County. The exact southward extent of the sandstone beneath the younger beds cannot be determined, but where the section is exposed south of the coal fields the sand member is missing, this area doubtless having occupied a position in the early Chester sea at a somewhat greater distance from the shore line to the north and beyond the reach of the sands of the Bethel formation. The absence of the Bethel Sandstone in the Edmonson County area gives a much different aspect to the Lower Chester sedimentary sequence than that which is exhibited in the western counties of Kentucky. Even the limestones themselves are much purer than in the nearer shore areas where the Bethel Sandstone is present, and where important shale members are interbedded with the limestones.

The name Gasper has not been used in this report because of the mistaken interpretation of the section by the author of the name, and because if applied strictly as a substitute for the older Tribune, as it was intended, it has no validity, the name Paint Creek having several years priority. The hyphenation of the names Renault and Paint Creek seems to be altogether the wiser plan to pursue in this case, since this usage clearly shows the relationship of the limestone to the Chester section elsewhere.

Paleontology. Well preserved fossils are not abundant in the Renault-Paint Creek limestones in Edmonson County. The best preserved fauna in the formation is found in the upper part of the limestone where numerous examples of *Productus* together with some other brachiopods and other types are present in a well defined Productus zone. The best collection secured from the Productus zone in Edmonson County is from the exposures in the valley of Bylew Creek. A similar Productus zone is present in the Paint Creek formation in Caldwell County, near Princeton, and in the table below the collection from Bylew Creek is compared with a similar fauna from the Princeton Quadrangle.

	Fauna of Productus Zone From Bylew Creek	Paint Creek Fauna From Princeton Quadrangle
Triplophyllum spinulosum (M. E. & H.)		X
Schuchertella costatula (H. & C.)	X	X
Orthotetes kaskaskiensis (McChesny)	X	X
Chonetes chesterensis Weller		X
Productus inflatus McChesny	X	X
P. ovatus Hall	X	X
P. sp.	X	X
Diaphragmus elegans (N. & P.)	X	X
Camarotoechia purduei Girty	X	X
Dielasma illinoisensis Weller	X	
Girtyella indianensis (Girty)	X	X
Spiriferina spinosa (N. & P.)		X
Spirifer increbescens Hall	X	X
Martina sulcata Weller	X	
Reticularia setigera (Hall)		X
Eumetria vera (Hall)		X
Cliothyridina sublamellosa (Hall)	X	X
Composita trinuclea (Hall)	X	X
Phillipsia sp.		X
Cladodus sp.		X

The similarity of these faunas is striking, an especially important member of each being *Camarodrechia purduei,* a species which was originally described from the Morefield Shale of Arkansas. This is one of the rhynchonelloid shells, which as a group are among the least common brachiopods in the Chester faunas of western Kentucky and southern Illinois. Outside of Arkansas this species has been found only in the faunas enumerated above. On the basis of these faunas there need be little hesitation in correlating the higher portion of this limestone with the Paint Creek of the more western counties of Kentucky and of southern Illinois.

The most important collection which was made from the lower portion of this limestone in Edmonson County, is from an outcrop at Great Onyx Cave, only a few feet above undoubted Ste. Genevieve limestone with *Platycrinus penicillus* stem plates. This fauna contains the following species.

RENAULT LIMESTONE FAUNA AT GREAT ONYX CAVE

Campophyllum gasperense Butts
Talaracrinus cornigerus (Shumard)?
Productus ovatus Hall
Productus sp.
Dielasum arkansanum Weller?
Girtygella indianensis (Girty)
Spirifer pellaensis Weller
Cliothyridina sp.
Composita trinuclea (Hall)
Leiopteria sp.
Aviculopecten sp.

The *Talaracrinus* of the above fauna is highly characteristic of the Renault Limestone, this formation being the conspicuous Talarocrinus zone throughout the whole extent of the Lower Chester beds. In Edmonson County wherever these beds are exposed the characteristic bases and radial plates of this crinoid may be found by careful search. At some places where the lower beds of the Renault-Paint Creek Limestone are exposed they are fairly common and although they have been found to occur throughout this whole formation they are much more numerous in the lower part. Not infrequently good silicified specimens of *Talarocrinus* occur in the residuum of the beds. Silicified examples of the coral *Campophyllum gasperense* associated with the peculiar siliceous concretions which have been described on page 129 also occur abundantly in the residual clays at many localities. Specimens of this coral were found in situ at Great Onyx Cave with the associated species mentioned above. It had not been recognized in the Renault of the more wstern counties of Kentucky and southern Illinois and its presence in the Edmonson County region may be due to the fact that it was better adapted to the clearer water conditions which existed here farther from the ancient shore line.

The *Talarocrinus* zone and the Productus zone above are considered to be sufficient evidence to establish the existence of

both the Renault and Paint Creek equivalents in the continuous limestone sequence which occurs in Edmonson County between the Ste. Genevieve Limestone below and the Cypress Sandstone above.

Three small collections from the Renault-Paint Creek formation, which contain species not included in the above lists, are given below.

BROWNSVILLE PIKE 2½ MILES NORTH OF ROCKY HILL

Talarocrinus sp.
Composita trinuclea (Hall)
Enomphalus planidorsatus M. & W.
Naticopsis n. sp.
Holopea sp.

WARREN COUNTY—BEAVER DAM CREEK ¾ MILES NORTHEAST OF PENN CHURCH

Productus ovatus Hall
Diaphragmus elegans (N. & P.)
Girtyella indianensis (Girty)
Spirifer leidyi N. & P.
Cliothyridina sublamellosa (Hall)
Bellerophon sp.

WARREN COUNTY—TOP OF PILOT KNOB

Pentremites sp.
Girtyella indianaensis (Girty)
Spirifer increbescens var. *transversa* Hall
Cliothyridina sublamellosa (Hall)
Composita trinuclea (Hall)
Aviculopecten sp.
Platyceras sp.

In addition to the forms enumerated in the above lists several species of *Pentremites* and bryozoans, of which *Archimedes* is the most noteworthy, although not common, occur at many places and *Agassizocrinus* bases appear here and there.

Cypress Sandstone

Name. The Cypress Sandstone was named by Englemann[11] from Cypress Creek in Johnson and Union Counties Illinois.

[11]Henry Englemann: "The Lower Carboniferous System as Developed in Southern Illinois." St. Louis Acad. Sci. Trans., Vol. 2 (1863), p. 189.

Distribution. This formation outcrops extensively in Edmonson County. It caps the Dripping Spring Escarpment which rises sharply above the low sink hole country along the whole southern edge of the county. It forms the tops of all the ridges and hills of the valley sink area, with the exception of the hill one and one-half miles northeast of Mammoth Cave, where it outcrops upon the hill sides, the summit being composed of younger formations. From the valley sink area it outcrops almost continuously along Green River and extends up into the tributary valleys nearly to Brownsville. The Cypress outcrops continuously from the Dripping Spring Escarpment down Alexander Creek to Parrish Mill Ferry on Green River and also occurs in the small hollow immediately to the west. It extends up each of the prongs of Beaver Dam Creek for over a mile beyond Rhoda and also down the main valley to within one mile of Green River. A small isolated area of this sandstone occurs in the bed of the same creek a mile east of Chalybeate Spring, and farther up the stream a mile and a half west of Liberty, the northern slope from the Dripping Spring Escarpment coincides with the dip slope of the Cypress and this sandstone outcrops in the bed of the stream for about one mile. Near Liberty there are two small, isolated areas of Cypress, one in a sink hole a quarter of a mile to the southeast and the other at the very headwaters of Beaverdam Creek one-quarter of a mile to the west.

North of Green River the Cypress is exposed in the lower part of Indian Creek and for a considerable distance up Pine Creek. Four of the eastern tributaries of Nolin River, First, Second, Bylew and Briar Creeks, have developed their beds for a considerable distance upon this formation. Farther to the east it outcrops upon the hillsides north of Green River all the way to the county line. It extends back into the tributary hollows, and in the case of Buffalo Creek, its outcrop has been carried back by erosian nearly to the heads of both prongs.

Thickness. In Warren County north of Bowling Green the Cypress Sandstone attains a thickness of 75 feet, but there is a general thinning of this formation to the east, and in Edmonson County its thickness probably averages about 60 feet. Measurements north of Green River indicate that there may be further thinning of the formation in that direction, as only 40 feet of

Cypress was observed just east of Sand Spring School. In Bylew Creek, however, its thickness is at least 50 feet.

Topography. The Cypress Sandstone is highly resistant to erosion and tends to form gently rolling, nearly level country, but the youthful streams have cut deep sided, miniature gorges in it. When attacked by erosion from the sides, by the removal of the underlying limestone the Cypress produces steep hillsides and in places precipitous cliffs are developed. In the western part of the county headward erosion by the streams has produced great cirque-like indentations in the sandstone outcrop. These indentations are roughly semicircular in form and the sandstone drops away in vertical cliffs up to 40 feet in height. The run off after a rain cascades down these cliffs, and most of them are impossible to scale. The development of these cirque-like indentations is less pronounced in the eastern part of the county, and although they occur here and there the heads of the hollows are mostly of the vertical V shaped type.

Lithologic Character. The Cypress is notably a massive sandstone formation. In Warren County north of Bowling Green shaly beds occur at a number of localities near the base of the formation and in the same vicinity shaly sandstones are present near the top. In Edmonson County, however, the Cypress is of a more uniform character. It is composed of sand grains of medium fineness, usually rather firmly cemented together. Some beds are so completely indurated that their texture is almost quartzitic. The sandstone surfaces are uniformly stained brown by iron oxide, this color also penetrating through the rock to a lesser degree. At Sand Hill in Warren County, two and one-quarter miles from the Edmonson County line, a horizon five or six feet in thickness, composed of pure white sand, occurs near the base of the Cypress. These beds are not nearly so firm as the ordinary Cypress ledges and they crumble readily. No such white sand was observed in Edmonson County.

The Cypress is commonly much crossbedded, the individual layers ranging from two to six inches in thickness while the more massive beds attain a thickness of two feet or more. This formation is ordinarily strong and resistant to stresses and does not commonly slump except along an open face. At a few localities, however, there are sink holes completely rimmed with sand-

stone which could only have been produced by the collapse of the sandstone roof of a cavern in the underlying limestone. Such sink holes occur south and east of Little Hope School, southeast of Liberty and southeast of Maple Spring School. The largest example observed in the district, about one mile in diameter, is located in Warren County just southeast of Sand Hill.

The Cypress as a whole is unfossiliferous, although here and there at various horizons throughout the formation beds may occur which contain the casts of a few varieties of brachiopods and pelecopods. In Warren County, in the neighborhood of Anna about three and three-quarter miles from the Edmonson County line, there is a horizon in the upper part of the Cypress persisting for over a mile containing abundant and well preserved casts of fossils. The bed is composed of medium sized sand grains stained brown by iron and the fossils are well preserved as internal casts and their identity is readily determinable. One of the localities where this horizon is exposed is by the roadside north of the creek at Anna. This locality is particularly interesting because of the occurrence of another horizon only 10 feet below, containing abundant remains of several species of plant fossils beautifully preserved. These forms occur in a fine grained, light brownish grey shale. In the best specimens the carbonaceous matter has been entirely removed and the vein patterns preserved by the introduction of fine threads of limonite. These two fossil localities separated stratigraphically from each other by only ten feet show conclusively that during the deposition of the Cypress, conditions suitable for the accumulation of both terrestrial and marine types of life alternated one wth the other. It is possible that some part of the Cypress is a terrestrial deposit; certainly the sediments were laid down in very shallow watter. It is surprising that forms of life usually found in calcareous sediments indicative of deeper and clearer waters of the sea, should occur anywhere in such a formation as the Cypress in such abundance as that which locally occurs.

Residual soil derived from the Cypress is composed almost entirely of sand, grey or light brown in color. On the hill sides talus accumulations of sandstone blocks of all dimensions are of

universal occurrence below the Cypress outcrop. The soils which occur overlying the Cypress on the hill tops preserving a portion of the old base-leveled surfaces are not typically residual, much of the material present being inherited from alluvium originally accumulated upon the high level flats.

Stratigraphic Relations. It has been stated in a previous paragraph that the Cypress is probably separated from the underlying Renault-Paint Creek by a slight unconformity. It is overlaid in turn by the Golconda Limestone which is believed to be completely conformable. This contact is rarely exposed but the Cypress commonly becomes somewhat shaly in its upper part and a shale bed 5 feet or more in thickness is almost always present at the base of the Galconda, the absence of such a shale bed having been observed at only two localities within Edmonson County, where the section is fully exposed. At one of these localities, in the bed of a tributary of Beaverdam Creek, which crosses the Brownsville-Rocky Hill Pike, one and one-half miles north of Rhoda, Golconda Limestone may be seen resting directly upon Cypress Sandstone, no transitional phase being present.

Correlation. The Cypress Sandstone is continuously present in the Chester section from Union to Hardin Counties, Illinois, and thence across the Ohio River into Kentucky and along the southern edge of the Western Coal Field to Edmonson County and beyond. This formation is the same as the Big Clifty Sandstone of Norwood[12] and theoretically it is the equivalent of bed No. 1 in Ulrich's Birdsville section,[13] but is not the same as this author's Cypress Sandstone in "The Lead, Zinc and Fluorspar Deposits of Western Kentucky."[14]

Paleontology. Fossils are restricted to a few horizons in the Cypress Sandstone, and that which occurs near the top in the vicinity of Anna is the only one where recognizable specimens occur as internal casts. One layer of the sandstone about six inches in thickness is literally crowded with fossils, but the number of species is rather limited as is shown by the following list.

[12] C. J. Norwood: "Report on the Geology Adjacent to the Louisville, Paducah and Southwestern Railroad." Geol. Surv., Ky. N. S., Vol. 1 (1876), p. 369.
[13] E. O. Ulrich: "The Lead, Zinc and Fluorspar Deposits of Western Kentucky." U. S. G. S. Prof. Paper 36 (1905).
[14] Ibid.

CYPRESS SANDSTONE ¾ MILE EAST OF ANNA

Diaphragmus elegans (N. & P.)
Dielasma illinoisensis Weller
Girtyella brevilobata (Swallow)
Spiriferina spinosa (N. & P.)
Spirifer leidyi N. & P.
Eumetria vera (Hall)
E. costata (Hall)
Cliothyridina sublamellosa (Hall)
Composita trinuclea (Hall)
Sphenotus sp.

Sandstone blocks containing numerous fossils as internal casts occur in the railroad cut at the western corporation boundary of Glasgow Junction just one mile east of the Edmonson County line. These blocks are undoubtedly from the Cypress and owe their preservation in their present position from having slumped down into an ancient sink hole of which no trace now remains. The fauna from these residual sandstone blocks is considerably different from the one cited above as the following list shows. The presence of *Camarophoria explanata* is of particular interest as this species is typical of the Middle Chester formations.

RESIDUAL SANDSTONE IN RAILROAD CUT WEST OF GLASGOW JUNCTION

Productus ovatus Hall
Camarophoria explanata (McChesney)
Dielasma illinoisensis Weller
Girtyella brevilobata (Swallow)
Spirifernia spinosa (N. & P.)
Spirifer leidyi N. & P.
Cliothyridina sublamellosa (Hall)
Composita trinuclea (Hall)
Platyceras chesterense M. & W.
Phillipsia sp.

Plant fossils, collected along the roadside just north of Anna from a shale occurring ten feet below the bed carrying marine invertebrates, have been referred to Dr. A. C. Noe for identification. He reports the presence of the following forms:

CYPRESS PLANT FOSSILS—ANNA, KENTUCKY

Adiantoides oblongifolius Gopp
Adiantites sp.
Archeopteris sp.
Cardiopteris sp.
Palmatopteris furactus var. *lincata* Brong
Lepidodendron culmianum Fischer
L. (leaves)
Trigonocarpus sp.

GOLCONDA LIMESTONE.

Name. The Golconda Limestone was first named in print by Butts[15] from Golconda, Illinois, a short distance above which town excellent exposures occur in the Ohio River bluffs.

Distribution. Outcrops of the Golconda Limestone are widely distributed throughout Edmonson County, where it almost always occupies a comparatively narrow band between the under and overlying sandstones. This formation is exposed on the northward dipping slope from the summit of the Dripping Spring Escarpment as far east as Liberty, from which locality it swings to the north and northwest, reaching Green River at Turnhole Bend and thus bordering the Valley Sink Area upon its western side. It outcrops continuously from its most southerly occurrences to Green River along both Beaverdam and Alexander Creeks and extends southward for considerable distances in the two small hollows immediately west of the latter stream. It outcrops along both sides of Green River from Parrish Mill Ferry to Turnhole Bend and thence along the north side only to the county line. A few isolated remnants of the formation may occur upon some of the hill tops which intervene between the valley sinks, and the large hill one and one-half miles northeast of Mammoth Cave is outlined by this limestone. The Golconda is exposed in numerous sink holes entirely surrounded by Hardinsburg Sandstone, as is the case on the east side of Beaverdam Creek south of Rhoda.

On the north side of Green River isolated areas of the Golconda are exposed by faulting in both Crooked and Honey Creeks. The exposures on the hillsides upon the north bank of the river have been carried back by erosion in Long and Lime-

[15] Charles Butts: "Mississippian Formations of Western Kentucky." Ky. Geol. Surv. (1917), p. 91.

stone Branches and in Indian Creek, also the Golconda extends far up near the heads of both the Wet and Dry Prongs of Buffalo Creek. The tributaries of Nolin River in which the Golconda is extensively exposed are Pine, Pigeon and Dismal Creeks to the east, and it is also exposed along Nolin River itself from its junction with Green River to a point about one mile north of the mouth of Brier Creek except for a short stretch between Pine and Bylew Creeks where it has been removed by pre-Pennsylvanian erosion.

Thickness. The thickness of the Golconda Limestone is not easy to determine with exactness because of the slumping of the beds at both its upper and lower contacts, but it probably varies between 20 and 40 feet. In general there seems to be a thinning of the formation to the east. In the western part of Edmonson County it maintains itself with nearly uniform thickness of about 40 feet, but farther to the east it is somewhat reduced and probably averages between 30 and 35 feet in thickness.

Topography. The Golconda Limestone is very non-resistant to the processes of weathering and rarely occurs as the uppermost formation in level areas, and then only when protected by a heavy mantle of residual material derived from the overlying Hardinsburg Sandstone. It characteristically outcrops on steep hillsides, and even then it is commonly covered by talus accumulations. In places it is exposed in vertical bluffs along streams which provide the means for removing fallen material which otherwise would cover entirely the limestone ledges. Only one locality, on the east side of Alexander Creek, one and one-quarter miles southeast of Parrish Mill Ferry, is known where the Golconda stands out conspicuously and forms a small terrace upon the hillside, and here its exposures are more prominent than those of either the Cypress or Hardinsburg Sandstones. The Golconda is an easily soluble limestone and sink holes are of common occurrence in it. They are generally of small size but are steep sided and frequently develop through the overlying Hardinsburg Sandstone.

Lithologic Character. With the exception of the shale bed nearly everywhere present at the base of the Golconda and a little shale which seems to be present at the top in a few localities, this formation is composed entirely of limestone. One-

quarter of a mile west of the Brownsville-Rocky Hill Pike, in the bed of the hollow which crosses it one and one-half miles northwest of Rhoda the basal shale is absent and the limestone beds rest directly on the Cypress. These relations have been observed at only one other locality and in every other section where this contact has been seen, shale separates the limestone from the sandstone. This basal shale member of the Golconda varies in thickness from its usual development of about five feet to a possible maximum of ten feet. It is somewhat uniformly dark grey in color, is fine grained and possesses well defined partings. At a few localities a portion of this shale is highly carbonaceous and contains abundant rather inperfect carbonized plant fossils, mostly leaves of *Lepidodendron*. A rather extensive thin coal is reported at approximately this horizon along Green River in Edmonson County. A short distance east of Sand Hill in Warren County and at several localities farther to the west it was formerely taken out on a small scale for smithing purposes. This coal has not been observed by the writer but it is probable that it occupies more or less the same position as the local carbonaceous horizon in the shale mentioned above.

The shale at the base of the Golconda Limestone constitutes an impervious bed which is the reason for the existence of the numerous springs which issue at the base of the formation, this contact between the limestone and underlying shale being the spring horizon par excellence in Edmonson County. The water from these springs is of fine quality and the flow from some of them is very great. Their presence is so characteristic of this horizon that the base of the Golconda can be determined with considerable accuracy by the location of the springs in places where no exposures are to be found.

The limestone of the Golconda is generally light grey in color, similar to that of much of the lower limestone of the region. In texture it ranges from fine to coarsely crystalline but does not contain beds as dense as some of those which are so commonly present below the Cypress. The individual limestone beds vary from a few inches to a foot or more in thickness and are separated from each other by thin shaly partings. This formation is particularly susceptible to solution and in many places is honeycombed with channels. These channels are espe-

cially well developed in the upper part of the limestone just beneath the Hardinsburg where the latter outcrops over wide areas. They pursue tortuous courses, divide, branch and rejoin one another and locally they are closely spaced and may attain a width

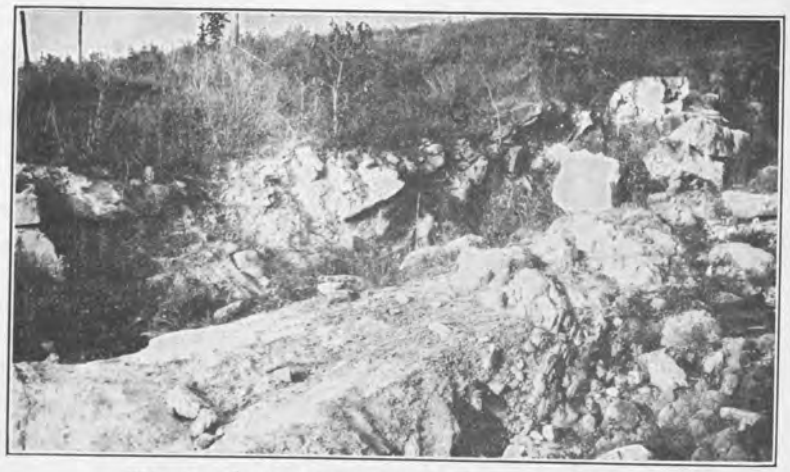


FIG. 33. HARDINGSBURG SANDSTONE DEBRIS.
This weathered formation is slumped down into solution channels in the Golconda Limestone as shown in the old road just east of Rhoda. Two pinnacles of the Golconda are indicated by the letter G. The sandstone blocks stand at all angles and at first glance give the impression of intense deformation.

and depth of ten feet or more. Into these solution channels the Hardinsburg Sandstone collapses, forming in many places sink holes which are entirely rimmed by sandstone. This process is responsible for the folded and tumbled blocks of sandstone occurring between pinacles of the Golconda Limestone which at first glance might be taken for intense local deformation. This accumulation of tumbled sandstone blocks also serves to mask the limestone and makes the presence of exposures on hilltops and gentle hillsides a great rarity.

Small amounts of grey shale have been seen to immediately overlie the limestone beds of the Golconda at several localities in Warren County north of Bowling Green, but such exposures have not been observed in Edmonson County although the presence of numerous springs at the top of the Golconda in a few restricted areas may be an indication of its presence. Such springs

occur locally west of Liberty in the upper part of the valley of Beaverdam Creek.

The Golconda Limestone weathers to a residual clay of a deep red color which is always gritty from the admixture of Hardinsburg sand. In Warren County south of Sand Hill and Penn Chapel School the Golconda residuum contains numerous cherts which have been formed by the silicification of beds of the limestone. The exterior surfaces of these chert fragments are usually stained brownish by iron oxide, but the insides are chalky white in color. They are much leached out, but nevertheless they preserve almost perfectly the structure of the limestone and the enclosed fossils. In this region the limestone exposures are scarce and consequently such cherts are a valuable guide in tracing the extent of the formation. In Edmonson County, however, cherts are of much less common occurrence.

Stratigraphic Relations. The Golconda Limestone probably overlies the Cypress Sandstone with entire conformity since beds of a somewhat transitional nature occur at most localities where this contact has been observed. These transition beds include shaly sandstones and sandy shales at the top of the Cypress and the shale bed which so commonly occurs at the base of the Golconda.

The Golconda is overlain unconformably by the Hardinsburg Sandstone, the unconformity being well exposed in the lower part of the valley of Dismal Creek. Here massive sandstone rests directly upon the limestone, the contact being somewhat uneven due to the development of small erosional channels in the limestone surface.

Correlation. The Golconda formation is a distinct unit in the Chester Section at all places where it has been observed to the west. It extends completely across southern Illinois and its outcrops surround the western Kentucky coal basin, passing in a northwestward direction into southwestern Indiana. In all probability further investigation will reveal its presence both to the east and south on the other flank of the Cincinnati Arch. The presence of characteristic Golconda fossils at the northern end of Lookout Mountain, Tennessee[16] proves the southeastward extension of the formation to this locality.

[16] Charles Butts: "Mississippian Series of Eastern Kentucky." Ky. Geol. Surv., Ser. 6, Vol. 7 (1922), p. 171.

Paleontology. The Golconda Limestone is rather unfossiliferous and no collections were obtained from this formation in Edmonson County. In several places, however, *Camarophoria explanata* (McChesney), *Prismopora serrulata* Ulrich and *Archimedes laxus* Hall were observed. These three species have never been recorded from beds below the Middle Chester. A few species of *Pentremites* together with *Agassizocrinus* and *Eupachycrinus* occur at some localities. Brachiopods are comparatively rare. *Pterotocrinus capitalis* (Lyon) which is a most characteristic guide fossil of the Golconda in southern Illinois and the western part of Kentucky was nowhere observed in Edmonson County, although particular search was made. Where it has been observed to the west this species is confined to a rather restricted horizon near the base of the formation. It is possible either that the lower beds of the Golconda are absent from Edmonson County or else that this highly specialized crinoid was not adapted to the clear water conditions which prevailed in this region and was therefore confined to a rather constricted and narrow belt nearer the margin of the sea as it existed at this time.

Hardinsburg Sandstone.

Name. The Hardinsburg Sandstone was named by Butts[17] from exposures at Hardinsburg in Breckenridge County, Kentucky.

Distribution. This formation outcrops extensively in the southern part of Edmonson County where it is the uppermost formation over large areas of comparatively flat country lying between the southwest county line and Alexander Creek; between Alexander and Beaverdam Creeks; and between Beaverdam Creek and the Valley Sink Area. A number of small areas of Hardinsburg, isolated by erosion, occur at intervals upon the northward dipping slope from the Dripping Spring Escarpment. There are also a few isolated patches preserved upon some of the hilltops in the Valley Sink Area. The north western extension of the hill lying between Houchins Valley and Green River is capped by the Hardinsburg and it is also exposed upon the

[17] Charles Butts: "Mississippian Formations of Western Kentucky." Ky. Geol. Surv. (1917), p. 96.

upper slopes of the higher portion of the hill south and southeast of Mammoth Cave School.

The Hardinsburg Sandstone is exposed continuously along both sides of Green River from about a mile below Monroe Landing to Turnhole Bend, where the southern exposures swing around upon the west side of Double Sink and connect with those of the extensive southern flats. Both Alexander and Beaverdam Creeks have cut their channels below the Hardinsburg throughout their entire courses and along both sides of each of these streams the formation outcrops without interruption from the southern flats to Green River. The Hardinsburg is exposed in both of the small hollows directly west of Alexander Creek, from Green River nearly to their heads. An isolated patch of this sandstone is exposed in Sally Branch south of Wainfield School and it occurs also in the bed of Little Beaverdam Creek from the county line down stream for a distance of about half a mile as well as into a number of the smaller tributaries of this stream which cut back from Warren into Edmonson County.

North of Green River the Hardinsburg Sandstone appears in the bed of Crooked Creek and in two isolated stretches, separated by faulting in Honey Creek. Erosion has carried the Green River exposures back for a considerable distance in Indian Creek and both prongs of Buffalo Creek. In the vicinity of Cade, the Hardinsburg caps the lower flat portion of the hilltops as it similarly does farther to the east about Little Jordan School.

The Hardinsburg outcrops upon both sides of Nolin River from its mouth to Pine Creek. It extends up both First and Second Creeks, being exposed upon the hillsides, and occurs also upon the south side of Pine Creek to the west of the river. The Hardinsburg exposures along Nolin River, which were interrupted at the mouth of Pine Creek, are resumed at the mouth of Dismal Creek and continue northward to the mouth of Longfall Creek. The bed of Dismal Creek is cut upon this sandstone, from near its mouth to the flat one mile east of Bee Spring. This formation is exposed extensively along Brier Creek from its mouth nearly to its headwaters southeast of Straw and isolated stretches occur in the beds of Longfall, Wolf and Dog Creeks and also in the upper portions of a number of tributaries of Dog Creek between Sanders Store and the northeast county line.

Thickness. In most localities the exact thickness of the Hardinsburg Sandstone cannot be determined because of the great amount of slumping of the lower beds due to the solution of the underlying Golconda Limestone, but in general the observed thicknesses vary between 30 and 40 feet. As a whole the formation seems to be developed rather uniformly to its maximum thickness.

FIG. 34. BLUFF OF HARDINSBURG SANDSTONE.
This outcrop is on the east side of Dismal Creek one-half mile above its mouth. The Hardinsburg is ordinarily rather non-resistant to the processes of weathering and erosion.

Topography. The most characteristic topographic features produced by the Hardinsburg Sandstone are the large flats in the southern part of the county which have developed upon the surface of this formation. Smaller flats of a similar nature, although more dissected by erosion, are present north of Green River about Cade and Little Jordan School. Where valleys are developed upon these Hardinsburg flats they are shallow and bordered by gentle slopes. Sink holes are abundant locally due to the collapse of the sandstone into channels dissolved in the underlying Golconda Limestone. Where the Hardinsburg is present upon the hillsides it forms somewhat steep slopes and in places more or less indistinct terraces are present. This formation rarely stands out as cliffs or bold escarpments, nor does it form cirquelike amphitheaters at the heads of the ravines as does the Cypress.

Lithologic Character. Fresh exposures of the Hardinsburg Sandtone resemble those of the Cypress lithologically. In general it is composed of beds of rather massive appearance, although shaly sandstone layers are common in many localities, and on the whole are much more conspicuous than in the Cypress. This formation is developed as a conspicuously massive unit at only one locality within Edmonson County, along Dismal Creek, one-half mile above its mouth. Here the Hardinsburg forms great overhanging bluffs and a tributary ravine has cut a miniature gorge through it.

The basal beds of the Hardinsburg Sandstone are commonly thinbedded and locally are slightly shaly, and in some places a bed of dark or almost black sandstone is present, one or two inches in thickness, so firmly cemented as to resemble quartzite. These basal beds are more or less impervious to water and springs are of common occurrence at this horizon.

The main portion of the Hardinsburg is composed of medium grained sandstone beds from an inch or two to a foot or more in thickness. As a rule they are considerably crossbedded and stained dark brown by oxide of iron. A considerable portion of the cementing material in these beds may be lime. As exposed in the stream beds the Hardinsburg appears as a rather resistant formation, the outcrops being clean cut and sharp in outline, but exposures on the hill tops and in the open are greatly in contrast with these, for the sandstone in such situations crumbles under the influence of the weather and rounded surfaces overlain by quantities of loose sand are formed. A good exhibition of this type of exposure may be seen on the north side of the Brownsville-Rocky Hill Pike one and one-quarter miles northwest of Pig.

The uppermost beds of the Hardinsburg Sandstone are nowhere well exposed, but it is probable that they become more shaly and pass somewhat gradually into calcareous shales at the base of the Glen Dean Limestone.

The conclusion might be reached that the presence of the Hardinsburg Sandstone upon the extensive flat lands in the southern part of the county, indicates that the formation is

highly resistant to weathering and erosion, but this is not the case. The Hardingsburg itself is easily broken down, but where the resulting residual material is allowed to accumulate it forms a most effective protecting blanket over the beds beneath. This residual material derived from the Hardinsburg is highly characteristic. In the course of weathering the sandstone beds are leached of their cementing materials and a spongy soft mass of sand remains which retains the bedded structure of the original sandstone. This sandy material slumps down along joints in the underlying sandstone and commonly becomes highly fractured. These fractures and the pore space between the sand grains then become filled with the tenaceous red clay residuum of the overlying Glen Dean Limestone, producing a compact sandy mass which is rather impervious and is not taken into suspension easily by running water.

The Hardinsburg residuum is therefore a red sandy mass often preserving the original bedding of the sandstone. Where the beds have not been disturbed, conspicuous secondary structures are developed such as those shown in cuts along the Brownsville-Rocky Hill Pike a short distance northwest of Pig. In places where the sandstone has been shattered either by collapse into subjacent solution channels or along faults, the red sandy residual material contains many blocks of weathered sandstone imbedded at all angles.

Stratigraphic Relations. The Hardinsburg Sandstone overlies the Golconda Limestone unconformably. This unconformity is not conspicuous at most of the localities where the contact has been observed. Shale occurs in places at the top of the Golconda and the basal Hardinsburg is commonly composed of somewhat shaly and thinbedded sandstones, but at one locality on the east side of Dismal Creek one-half mile above its mouth a tributary hollow has undercut a bluff of Hardinsburg Sandstone and perfectly exposed the unconformity for a considerable distance. Here there is no suggestion of transitional beds and the massive sandstone rests directly upon compact limestone. Moreover the line of contact between the two formations is slightly irregular and plainly shows signs of small erosional channels developed upon the limestone surface, but no conglomerate is present.

The Hardinsburg Sandstone is overlain with apparent perfect conformity by the Glen Dean Limestone.

Correlation. The Hardinsburg Sandstone is not present as a continuous formation of the Chester section in southwestern

FIG. 35. THE GOLCONDA-HARDINSBURG UNCONFORMITY.

This exposure is on the east side of Dismal Creek one-half mile above its mouth. The sandstone which is unusually massive at this locality rests upon the undulating surface of the limestone.

Illinois, but it is represented by a discontinuous sandstone layer in the midst of the formation to which the name of Okaw[18] (Golconda and Glen Dean Limestones) was originally given. To the southeast, however, the Hardinsburg makes its appearance as a persistent formation and is well developed on all sides of the western Kentucky coal basin both in Kentucky and its extension into Indiana. It has been recognized in Overton County, Tennessee, but is absent from the section east of the Kentucky Blue Grass Region.[19]

Paleontology. Altho casts and impressions of invertibrate fossils have been obtained from residual blocks of the Hardinsburg Sandstone at several localities in Warren County no fossiliferous horizon has been observed in situ.

[18] Stuart Weller: "Stratigraphy of the Chester Group in Southwestern Illinois." Ill. Acad. Sci. Trans., Vol. 6 (1914), p. 127.

[19] Charles Butts: "Mississippian Series of Eastern Kentucky." Ky. Geol. Surv., Ser. 6, Vol. 7 (1922), pp. 169 and 171.

Glen Dean Limstone.

Name. The Glen Dean Limestone was named by Butts[20] from the village of Glen Dean in Breckenridge County, Kentucky.

Distribution. This formation is exposed continuously along both sides of Green River from a point one and one-quarter miles east of the mouth of Bear Creek to the mouth of Buffalo Creek. Throughout this distance erosion has carried the outcrop of the formation back almost to the heads of all the tributary hollows upon both sides with the exception of Alexander and Beaverdam Creek. These two streams rise upon the northern slope from the Dripping Spring Escarpment among beds much lower in the Chester Series and the Glen Dean occurs only along the lower parts of their valleys.

South of Green River the area over which the Glen Dean outcrops may be divided roughly by a line starting at the southwest county line, from there extending nearly east to Sulphur Springs, thence northeast to Rhoda, thence down the course of Beaverdam Creek for one and one-half miles, thence northeast to a point about midway between the mouth and head of Ivy Branch and finally down the valley of this stream to Green River at Houchins Ferry. In the region northwest of this line the Glen Dean does not cap the hills but is exposed upon the slopes from beneath a Pottsville covering. South and east of this dividing line the Glen Dean outcrops extensively upon the flatter hilltops, holding upon its surface, however, numerous knobs protected by Pottsville caps. A long, narrow remnant of the Glen Dean is present upon the east-west ridge lying one and one-quarter miles northeast of Mammoth Cave, where the formation occurs beneath a thin covering of Pottsville.

North of Green River and east of Buffalo Creek, the Glen Dean is present in a number of isolated patches upon the hilltops south of Mill Branch and Big Hollow. Upon three of these hills it outcrops beneath Pennsylvanian caps. Two small isolated exposures of the Glen Dean occur upon the hilltop near the county line northeast of Little Jordan School. The outcrop of the Glen Dean continuous with that occurring on the north side of Green River farther to the west extends far up into both

[20] Charles Butts: "Mississippian Formations of Western Kentucky." Ky. Geol. Sur (1917), p. 97.

prongs of Buffalo Creek, where it is interrupted by the pre-Pennsylvanian unconformity. It then skirts the upper slopes of the north-south ridge for a distance of one and one-half miles south of Stockholm and thence continues to the east in the upper portions of the northward rising branches of Ugly Creek.

The Glen Dean outcrops upon the hillsides above Nolin River throughout its entire course in Edmonson County with the exception of the stretch between Pine and Dismal Creeks. It is extensively exposed along the courses of First, Second, Dismal, Brier, Davis and Longfall Creeks, all tributary to Nolin River, but it does not occur in either Bylew or Pigeon Creeks. In the valley of Pine Creek the formation is present only in the heads of the small southern tributary ravines.

Isolated outcrops of the Glen Dean, not connected with any of those which have been enumerated, occur in Caney Hollow, whose bed is largely cut upon this limestone, and also continuously along Dog Creek from the point where it enters to where it leaves Edmonson County. These Dog Creek outcrops continue up Wolf Creek nearly to its head at Straw. The pre-Pennsylvanian unconformity has separated a small area of the Glen Dean from the Dog Creek outcrops in the beds of a group of the tributaries of this stream northeast of Sanders Store. Outcrops of the Glen Dean isolated by faulting occur in the heads of a number of hollows tributary to Dog Creek between Sanders Store and the county line.

Thickness. In Warren County, north and east of Bowling Green, the Glen Dean Limestone attains a nearly uniform thickness of 70 feet. In the western portion of Edmonson County a similar thickness is retained, but farther to the east this limestone may be reduced to about 60 feet. In the northeastern part of the county the development of the Glen Dean is not so uniform and over short distances it varies between 30 and 60 feet, 50 feet being its more usual thickness.

In those parts of the county where pre-Pennsylvanian erosion has removed the Leitchfield Formation the thickness of the Glen Dean varies from nothing to 60 feet, such differences being due to the differential erosion of the formation preceding the deposition of the basal Pottsville strata. Along the north side of Green River and east of Nolin River where the Pottsville rests

directly upon the Glen Dean, a nearly uniform thickness of about 20 feet has been observed.

Topography. Unlike the Golconda, the Glen Dean Limestone frequently occurs upon the uplands, over a considerable area in the southern part of Edmonson County. Here it underlies gently sloping and locally almost flat areas above which rise steep sided peaks that have been preserved by a capping of Pottsville. Throughout the greater part of its extent, however, the Glen Dean outcrops upon the hillsides, and in such situations its topographic expression is entirely similar to that of the other limestones of the county, forming steep slopes upon which outcrops are not infrequent although limestone cliffs are rare.

Lithologic Character. The limestone which makes up nearly the whole thickness of the Glen Dean is essentially similar in appearance to the underlying Golconda and local exposures of these two formations may not be distinguished from each other. Certain identification can be made only from the relations of the respective beds with the Hardinsburg Sandstone or by the thickness of the limestone, the Glen Dean being 50 to 100 per cent thicker than Golconda.

At the very base of the Glen Dean, shaly beds are locally present, but no true shale zone has been observed anywhere although somewhat impervious beds are present either at the base of the Glen Dean or at the top of the Hardinsburg, this contact being one along which springs commonly issue. This is the second most conspicous spring horizon of the county, it being exceeded only by a similar horizon at the base of the Golconda.

With the possible exception of the very base of the formation the Glen Dean is composed exclusively of evenly bedded limestone, the individual layers being about one foot in thickness. These layers are separated by thin shaly or marly partings which weather to a light grey or buff color and in places contain numerous bryozoans. The limestone itself is of a nearly uniform grey color and varies in texture from finely to coarsely crystalline. Oolites are locally present but beds in which they form a conspicious constituent of the rock are rare. The Glen Dean is sparsely fossiliferous with the exception of local occurrences of pentremites and bryozoans, but a persistant horizon in the upper part of the formation somewhat more marly than the

prevailing type of the limestone is literally crowded in places with the broken branches of the bryozoan *Tabulopora ramosa* together with a few examples of other forms.

FIG. 36. GLEN DEAN LIMESTONE IN WARREN COUNTY.

This exposure is two miles northeast of Sand Hill and one-third of a mile from the Edmonson County line. Deep and wide solution channels have been developed in the upper part of the formation.

Chert is locally developed in the lower part of the Glen Dean Limestone. This phase of the formation is best developed in Warren County at the junction of the two small hollows one and one-quarter miles northwest of Sand Hill. The cherts are tabular and irregular in outline and develop along the bedding of the limestone. They vary in thickness from one-half to two inches and are of no great extent laterally. They weather to a light brown, in places almost grey color and break up into small rhombohedral blocks, but the fresh cherts and the newly broken surfaces of the weathered ones are dark bluish grey tc black. These cherts are not developed throughout the whole extent of the Glen Dean and at most of the exposures of this formation none have been observed.

The Glen Dean Limestone weathers into rounded surfaces which if exposed in the open become somewhat bleached. The residual material is a stiff red clay similar to the other limestone residuum of the county and may locally contain rhombohedral chert fragments. The formation seems to be less soluble than the

older limestones but it has produced sink holes although the number is much smaller than those which have resulted from the solution of the Golconda. This however, may be due to the different situations of the two formations and the difference in the material which commonly overlies them rather than any actual difference in composition.

Stratigraphic Relations. The Glen Dean Limestone appears to overlie the Hardinsburg Sandstone with complete conformity although the contact between these two formations rarely is well exposed. In localities where the uninterrupted section has been observed no positive evidences of unconformity have been established although the change in the character of the sediment is somewhat abrupt. Commonly, the Hardinsburg becomes somewhat shaly at the top and a small amount of shale may occur at the base of the Glen Dean, but the transition between limestone and sandstone takes place within a few feet of sediments.

It is uncertain whether the Upper Chester beds overlie the Glen Dean conformably or not. There are certain features which rather suggest that an unconformable relation exists at this horizon, but exposures of the contact are almost invariably incomplete, some portion of the beds being covered by slumped material from above, but so far as can be determined the change in the character of the sediments seems to be unusually abrupt. The uppermost beds of the Glen Dean are compact limestones similar in character to those which make up the bulk of the formation below. The limestone seems to be directly overlain by beds varying in composition from massive sandstone, which may be the Tar Springs, to the shaly beds which constitute the greater portion of the Leitchfield Formation. The variation in thickness which is exhibited by the Glen Dean in various sections not far removed from each other in the northwestern portion of the county is another possible indication of unconformity.

Correlation. The Glen Dean Limestone continues as a well defined formation completely across southern Illinois and into Kentucky, and it outcrops continuously about the border of the western coal basin and extends across the Ohio River into Indiana. It is also beneath the Pennsylvanian in eastern Kentucky and as far south as Overton County, Tennessee. The

formation is the exact equivalent of the higher beds of the Okaw Limestone in the Mississippi River section in Illinois,[21] and it seems also to be the equivalent of the lower part of the Bangor Limestone of the southern Appalachian section.[22]

Palæontology. The lower portion of the Glen Dean Limestone is rather unfossiliferous but an abundant fauna occurs near the top. The bryozoans are by far the most conspicuous forms as the following lists show:

GLEN DEAN LIMESTONE AT BROWNSVILLE, ROAD BACK OF JAIL

Triplophyllum spinulosum (ME. & H.)
Amplexus sp.
Pentremites brevis Ulrich
P. okawensis Weller
Pterotocrinus (wing plates)
Fistulipora montifera McFarlan (n. sp.)
Eridopora punctifera Ulrich
Tabulopora tuberculata (Prout)
Anisotrypa symmetrica Ulrich
Fenestella tenax Ulrich
F. serratula Ulrich
Archimedes swallovanus Hall
A. proutanus Ulrich
A. terebriformis Ulrich
Polypora cestriensis Ulrich
Lyropora sp. (base)
Reteporina flexuosa (Ulrich)
Septopora subquadranus Ulrich
S. cestriensis Prout
Streblotrypa nicklesi Ulrich
Prismopora serrulata Ulrich
Glyptopora sp.
Productus ovatus Hall
Diaphragmus elegans (N. & P.)
Spiriferina spinosa (N. & P.)
Spirifer leidyi N. & P.
Cliothyridina sublamellosa (Hall)
Composita trinuclea (Hall)
Platyceras chesterensis M. & W.
Bellerophon sp.
Phillipsia sp.
Psephodus sp.

[21] Stuart Weller: "Stratigraphy of the Chester Group in Southwestern Illinois." Ill. Acad. Sci. Trans., Vol. 6 (1914), p. 127.

[22] Charles Butts: "Mississippian Series of Eastern Kentucky." Ky. Geol. Surv., Ser. 6, Vol. 7 (1922), p. 169.

T. *ramosa* (Ulrich)
Anisotrypa solida Ulrich
Fenestella sp.
Archimedes laxus Hall
A. *swallovanus* Hall
Polypora sp.
Lyropora sp.
Septopora subquadrans Ulrich
Rhombopora sp.
Prismopora serrulata Ulrich
Orthotetes kaskaskiensis (McCh)
Spirifer leidyi N. & P.?
Martinia sulcata Weller
Composita trinuclea (Hall)

Leitchfield Formation

Name. In 1877 Shaler applied the name Leitchfield Marls[23] to a group of beds occurring in the upper part of the Chester Series at Leitchfield, Kentucky. These beds early attracted considerable attention on account of their high percentage of potash and were recognized at a number of localities upon the borders of both the Western and Eastern Kentucky Coal Fields. In 1878 Moore stated that these upper Chester shales were well exhibited in the vicinity of Leitchfield in Grayson County and also were well exposed at the Buffalo Wallow near Cloverport in Hancock County.[24] In more recent years Glenn has applied the name Leitchfield to undifferentiated shales, limestones and sandstones occurring at the top of the Chester section in Webster County.[25]

In 1917, Butts proposed the name Buffalo Wallow for the undifferentiated beds, mainly shales, which occur in the upper part of the Chester Series above the Tar Springs Sandstone and named as his type locality the Buffalo Wallow located two miles west of Cloverport, Kentucky.[26] It is clear that these two names are equivalent, and since Leitchfield has a precedence of 40 years over Buffalo Wallow the latter name will be abandoned in this discussion.

[23] N. S. Shaler: "Reports of Progress." Geol. Surv. Ky., N. S., Vol. 3 (1877), pp. 46, 106 and 391.
[24] P. N. Moore: "On the Geology of the Region Adjacent to the Eastern Border of the Western Coal Field," etc. Geol. Surv. Ky., N. S., Vol. 4, Pt. 11 (1878), p. 13 (435).
[25] L. C. Glenn: "Geology and Coals of Webster County." Ky. Geol. Surv., Ser. 6, Vol. 5 (1921).
[26] Charles Butts: "Mississippian Formations of Western Kentucky." Ky. Geol. Surv. (1917), p. 112.

GLEN DEAN LIMESTONE ¼ MILE SOUTH OF HONAKERS FERRY

Triplophyllum spinulosum (ME. & H.)
Pentremites brevis Ulrich
Spirorbis sp.
Fistulipora excelens Ulrich
Eridopora punctifera Ulrich
Batostomella spinulosa Ulrich
Tabulopora ramosa Ulrich
T. *tuberculata* (Prout)
Anisotrypa macropora McFarlan (n. sp.)
A. n. sp.
Archimedes proutanus Ulrich
A. *swallovanus* Hall
A. *terebriformis* Ulrich
Polypora corticosa Ulrich
Septopora subquadrans Ulrich
Rhombopora tabulata Ulrich
Prismopora serrulata Ulrich
Diaphragmus elegans (N. & P.)
Spiriferina spinosa (N. & P.)
Spirifer cf. *leidyi* N. & P.
Composita trinuclea (Hall)

GLEN DEAN LIMESTONE HILLSIDE BY ROAD SOUTH OF DAVIS FERRY

Triplophyllum spinulosum (ME. & H.)
Agassizocrinus sp.
Fistulipora eximia Ulrich
Eridopora punctifera Ulrich
Tabulopora ramosa (Ulrich)
Anisotrypa solida Ulrich
Archimedes sp.
Lyropora sp.
Spiriferina spinosa (N. & P.)
Spirifer increbescens (Hall) var.
Cliothyridina sublamellosa (Hall)
Composita trinuclea (Hall)

GLEN DEAN LIMESTONE 1¾ MILES NORTHEAST OF ANNA, KENTUCKY

Triplophyllum spinulosum (ME. & H.)
Pentremites canalis Ulrich
P. *pyramidatus* Ulrich
Spirorbis sp.
Fitsulipora eximia Ulrich
Eridopora punctifera Ulrich
Tabulopora tuberculata (Prout)

In this report the name Leitchfield Formation is used to include all of the beds of Upper Chester age or everything above the Glen Dean Limestone and below the Pennsylvanian. The Tar Springs Sandstone so far as it is developed in Edmonson County, which Butts excluded from his Buffalo Wallow, is here included in the Leitchfield. What is doubtless the equivalent of this sandstone, in part at least, is of extremely unequal development in this county and grades laterally into shales of the typical Leitchfield character. Locally it is present as a somewhat massive sandstone 10 feet in thickness, elsewhere there may be as much as 30 feet of sandy shale and shaly sandstone at the base of the Leitchfield, but throughout the greater part of the county the shale rests directly upon the Glen Dean Limestone. Because of this situation these local sand beds will be referred to as the Tar Springs Member of the Leitchfield Formation.

Distribution. The Leitchfield Formation is seldom well exposed. At many localities its presence is to be inferred only from a steep talus covered slope separating the outcrops of the Pottsville and Glen Dean. Where observations show the Pottsville resting upon the Glen Dean or older formations the evidence of the absence of the Leitchfield is positive, but a talus covered interval between the highest Chester limestone and the Pennsylvanian commonly indicates the presence of these shaly beds, though such evidence is not positive except where the shales are actually exposed. Those areas where the Leitchfield Formation is known to be entirely absent within Edmonson County will be mentioned, but throughout the remaining portion of the area it may be assumed that the formation is present outcropping in a narrow belt immediately below the Pottsville.

The Leitchfield Formation is known to be wanting from a large portion of that part of the county which is drained by Nolin River, having been completely removed by pre-Pennsylvanian erosion from the area now drained by Pigeon and Pine Creeks which join the river from the west and throughout the drainage basins of Bylew, Second and First Creeks which are tributary from the east. The area from which the formation is absent also extends north from the basins of the creeks mentioned, the Pottsville resting directly upon the Glen Dean Limestone in the heads of the small southward rising hollows tributary to that branch of Dismal Creek which originates opposite Sycamore Branch as well as in the heads of all the tributaries which join Brier Creek from the south. It is absent also from the upper course of Brier Creek itself from the upper two-thirds of Wolf Creek and from Dog Creek from a point about half a mile above its junction with Wolf Creek to the point where it enters Edmonson County from the east. It is also absent from a portion of the tributaries of Dog Creek which head between Sanders Store and the county line, particularly from the heads of the southernmost of these hollows.

Two smaller areas apparently isolated from the more extended region throughout which the formation is wanting occur in the northern part of the county. The larger of these includes a large part of the headwaters of Dismal Creek northeast of Bee Spring while the smaller lies one-quarter mile northeast of Nolin School.

The Leitchfield Formation is entirely absent in the area drained by the northern tributaries of Green River between Nolin River and the east county line, with the possible exception of the hill which stands between these two rivers just east of their junction. West of Nolin and north of Green Rivers the formation may be absent from a part of the headwaters of Indian Creek north and a little west of Steep Hollow School and also upon the west side of Honey Creek one mile northwest of its mouth.

South of Green River the Leitchfield is present wherever the base of the Pottsville is exposed with the exception of the hill one and one-half miles northeast of Mammoth Cave and the hilltop one-third of a mile southwest of McCoys Landing.

Except along Bullock Branch outcrops of the Leitchfield Formation without the exposure of the underlying Glen Dean are confined to the drainage basin of Bear Creek. Along Green River the formation continues to outcrop downstream from the point where the Glen Dean disappears to the county line. Here these beds are exposed upon the south side of the river just above low water level but on the north side they are covered by alluvium. This Green River outcrop extends up Bullock Branch and occupies the floor of the valley continuously to its head south of Red Hill School.

Leitchfield strata are extensively exposed in the bed of Gulf Hollow from its head nearly to the junction with its main tributary from the north, in the bed of which valley the formation also outcrops. Leitchfield outcrops are present along the two tributaries of Beaverdam Creek, which lies north and northeast of Grassland. Limestone which undoubtedly belongs to the Leitchfield Formation is exposed along Sycamore Branch for a short distance above its mouth as well as upon both sides of Bear Creek just below the junction of this stream. Similar limestone is present for a short distance in the bluff of Bear Creek just east of the mouth of Watery Branch. Isolated patches of the Leitchfield occur in each of the two small hollows which join Bear Creek from the east between Mill and Nappers Branches. Exposures are also present along Bear Creek itself from the north county line to a point about one-third of a mile south of the mouth of Mill Branch. The Bear Creek outcrops of the formation in Grayson County extend southward into Edmonson County for short distances in the valleys of Nells and Shoals Branches.

Thickness. The thickness of the Leitchfield Formation in Edmonson County varies from nothing to about 125 feet. It is not present in the north central part of the county where it has been removed by the pre-Pennsylvanian erosion but it is present to a greater and greater thickness both to the north and south of this old channel. The Leitchfield attains its maximum development in the northern part of the county adjacent to the Grayson County line and doubtless the thickness of these beds continues to increase northward. The formation is also represented in Warren County by a greater thickness of beds than is anywhere exposed in Edmonson, at a locality one mile south of Youngs Ferry, limestone outcrops being present 160 feet above the top of the Glen Dean Limestone. Although the Leitchfield increases in thickness generally away from the pre-Pennsylvanian channel, this thickening is not uniform and many irregularities have been observed. The irregular character of the pre-Pennsylvanian unconformity indicates that much erosion took place and considerable relief was developed locally, but it is impossible to determine in detail the amount of this relief because of the imperfectly exposed sections which result from the slumping of the massive sandstones of the Pottsville where they occur at the base of the Pennsylvanian and because of the difficulties encountered in determining the exact contact where Pottsville shales overlie the Mississippian.

Topography. The outcrops of the Leitchfield Formation are confined entirely to the hillsides. The universal shaly character of these beds has permitted them to be eroded rapidly from all positions where they were not protected by more resistant overlying strata. The formation produces steep talus slopes upon which exposures are rare. In places these slopes constitute a conspicuous feature, especially where they occur at the base of bold Pottsville bluffs.

Lithologic Character. The Leitchfield Formation is composed largely of shales with minor interbedded limestone and sandstone members. The limestones are commonly thinbedded and of no great thickness and most of the sandstones are of a shaly character Individual beds exhibit marked lateral variation and a section taken at one locality may be much different from another one near by. Three horizons may be recognized throughout considerable areas within Edmonson County although they are not everywhere present. These horizons are: first, the Tar Springs Sandstone member; second, a massive limestone member about 45 feet above the base; and third, a yellowish impure limestone horizon about 100 feet above the base.

The Tar Springs Sandstone member varies in thickness between 0 and 30 feet. North of Bowling Green in Warren County one mile northwest of Fairview School it is a resistant sandstone and exerts a conspicuous influence in the development of the topography. Four and one-half miles east of here on the hillside south of Mt. Pleasant School this member is absent and at no locality farther east or north in either Edmonson or Warren Counties is it anywhere so well developed. On the northern outskirts of Sand Hill this member is represented by a single small ledge of sandstone while in the hill one mile to the northwest between 10 and 20 feet of sandy shale are probably the equivalent of this same horizon.

In Edmonson County the Tar Springs Sandstone member is represented locally by a few feet of massive sandstone closely overlying the Glen Dean or by a thicker deposit of flaggy or

shaly beds. In the bed of Little Beaverdam Creek one and one-quarter miles southeast of Watts School it is represented by dark shaly sandstone, but three-quarters of a mile up this stream and also one and one-quarter miles to the north at the mouth of the creek it is entirely absent. Scattered blocks of brown sandstone one-quarter of a mile southwest of Pine Grove School indicate the presence of this member in the saddle between the two Pottsville hills. The Tar Springs is represented by about 10 feet of fairly massive brown sandstone along the road a little less than a mile southwest of Mt. Zion School. In the upper part of Bullock Branch this member is composed of rather fine grained sandstone which locally forms bluffs five to eight feet in height. Three-quarters of a mile northeast of Asphalt there are 10 feet of thinbedded, wavy, buff colored sandstone containing a thin limestone bed near the center which overlies the Glen Dean and 15 feet of similar sandstone are exposed one and one-half miles southeast of Houchins Ferry.

On the north side of the pre-Pennsylvanian channel shaly sandstone beds are of more common occurrence at the base of the Leitchfield, beds of this character reaching a thickness of 15 feet being exposed in the upper part of Dismal Creek one mile northeast of Bee Spring and a similar thickness is present along Nolin River a short distance east. At Dog Creek in Hart County less than a mile from the northeast boundary of Edmonson County these beds exhibit a thickness of about 30 feet. Near the mouth of the hollow which joins Bear Creek from the east nearly midway between Mill and Nappers Branches a five foot stratum of thin bedded fine grained rather hard sandstone occurs within the Leitchfield, but the Glen Dean is not exposed at this locality, and it is uncertain whether the bed should be regarded as Tar Springs.

The massive limestone member of the Leitchfield Formation about 45 feet above the Glen Dean contact varies in thickness between 4 and a possible maximum of 20 feet. Where this member is represented by beds less than four feet in thickness it ceases to be conspicuous and cannot be distinguished from other limestone beds which may be interbedded with the shales. In Warren County this limestone is present in the section northeast of Fairview School but is absent near Mt. Pleasant School.

It is well developed on the west side of Little Beaverdam Creek one mile southeast of Watts School. It is widely exposed north of Green River in the upper part of Bullock Branch and in the finger-like extensions of Caney Hollow as well as in the central and lower part of the valley of Dismal Creek. It is probable that the isolated limestone exposures along Bear Creek are the continuation of this bed to the westward. Numerous other occurrences of this limestone member have been observed but it seems to be absent from the section in the extreme northeastern part of the county. It is not unusual to find the Pottsville resting upon this limestone member of the Leitchfield. It is a somewhat massive, evenly bedded, grey, finely crystalline limestone and is much more resistant to erosion than any other part of the formation.

FIG. 37. LEITCHFIELD FORMATION.
A near view of shales in the lower part of this formation on the hillside above Green River just west of the mouth of Little Beaverdam Creek.

A peculiar type of yellowish impure limestone has been observed at two localities in Edmonson County, one in Warren County and one in Hart County. This limestone occurs as a thin bed or several thin beds separated by shales. The limestone is of a yellowish color and earthy texture and appears as if it has been subjected to prolonged weathering. It is structureless in itself but is cut in all directions by numerous fine calcite veins with highly irregular walls. In Edmonson County this bed is

present on the hill one-third of a mile northeast of the mouth of Davis Creek and just south of the county line a little more than a mile northeast of Salem School. The Hart and Edmon-

FIG. 38. ERODED LEITCHFIELD SHALE.
A gully developed in shales in the lower part of the Leitchfield Formation at the same locality as figure 37.

son County occurrences lie about 100 feet above the base of the Leitchfield Formation while at the Warren County locality the yellowish limestone occurs 160 feet above the Glen Dean.

The shales which make up the greatest part of the Leitchfield Formation are generally grey or bluish in color and are finely laminated. Sandy lenses which are present locally are coarser and less evenly bedded. Red and green shales are a conspicuous feature of the formation at some localities. The green color varies from dull to olive shades while the red is usually of a deep maroon tinge. These colored shales are well exposed on the west side of Little Beaverdam Creek at its mouth and to a

less extent two miles directly south of this locality, also at the junction of the tributary ravines of Caney Hollow. At all of these localities the Tar Springs Sandstone Member is absent and the variegated shales occur but a short distance above the top of the Glen Dean Limestone.

Some of the shales in the upper part of the Leitchfield weather to a plastic clay of a rather vivid green color although when fresh they are dark grey and similar in all other respects to the shales which occur lower in the formation. Thinbedded limestones occur in the upper part of the formation at irregular intervals. These beds are usually lenticular in form and are of no great lateral extent. They are not a conspicuous feature of the Leitchfield of Edmonson County being much better developed along the Bowling Green-Horse Branch road in Warren County. Locally some of these limestone beds are highly fossiliferous but such occurrences are not common. As a whole fossils are rare in the Leitchfield Formation.

The following sections illustrate the types of strata which occur within the Leitchfield and also the variability of the formation from place to place:

½ MILE NORTH OF PINE GROVE SCHOOL

Alternating yellowish green shales and thin limestone beds	20 Feet
Blue shale	20 Feet
Glen Dean Limestone	

NOSE OF HILL EAST OF NEGRO CREEK

Pottsville conglomerate	
Lenticular grey crystalline limestones 1 to 3 feet thick and interbedded shale	10 Feet
Blue shale weathers greenish	15 Feet
Yellowish brown weathered shale	10 Feet
Sandy shale and thin limestone beds	15 Feet
Glen Dean Limestone.	

1½ MILES NORTHEAST OF SANDERS STORE

Pottsville sandstone.	
Heavy grey crystalline limestone	5 Feet
Greenish plastic shale	5 Feet
Bluish thinbedded and shaly sandstone	5 Feet

HILLSIDE WEST OF DOG CREEK SETTLEMENT, HART COUNTY

Grey limestone boulders	
Shale	12 Feet
Yellowish shaly limestone	3 Feet
Shale	5 Feet
Yellowish limestone	1 Foot
Shale	8 Feet
Flaggy sandstone	2 Feet
Slope covered	40 Feet
Shaly sandstone	30 Feet
Slope covered	10 Feet
Glen Dean Limestone	

WHITE OAK BRANCH OF BEAVERDAM CREEK

Blue shale	20 Feet
Crystalline limestone	1 Foot
Blue shale	2 Feet
Shaly sandstone	2 Feet
Blue shale	6 Feet
Glen Dean Limestone	

AT JUNCTION OF BRANCHES OF CANEY HOLLOW

Pottsville sandstone	
Slope covered	20 Feet
Limestone	10 Feet
Shale	5 Feet
Sandstone	3 Inches
Shale	35 Feet
Glen Dean Limestone	

BEAR CREEK NORTH LINE OF EDMONSON COUNTY

Pottsville sandstone	
Slope covered	25 Feet
Yellowish limestone	1 Foot
Slope covered	8 Feet
Grey sandy shale	5 Feet
Yellowish limestone	1 Foot
Grey shale	6 Feet
Yellowish shaly limestone	6 Inches
Grey shale	9 Feet
Porous and fiberous chert	2 Inches
Grey shale	11 Feet
Finely crystalline limestone	13 Feet
Grey shale, some fine sand	11 Feet
Sandy shale and shaly sandstone	6 Feet
Slope covered to Bear Creek	26 Feet

ONE MILE NORTHWEST OF BEE SPRING

Pottsville coaly shale	
Limestone beds 1 to 2 feet thick and interbedded shale	5 Feet
Thinbedded wavy sandstone	5 Feet
Alternating shales and thin limestone layers 1 to 6 inches thick	20 Feet
Glen Dean Limestone	

HILLSIDE WEST OF MOUTH OF LITTLE BEAVERDAM CREEK

Green shale	6 Feet
Sandy shale	1 Foot
Olive green shale	4 Feet
Red shale	2 Feet
Olive green shale	3 Feet
Red shale	2 Feet
Black shale	2 Feet
Impure fossiliferous limestone and shale	1 Foot
Greenish shaly sandstone	4 Feet
Black shale	6 Feet

HILLSIDE NORTHEAST OF MOUTH OF DAVIS CREEK

Yellowish limestone fragments	
Shaly sandstone and green shale	5 Feet
Slope covered	45 Feet
Limestone	8 Feet
Slope covered	22 Feet
Sandstone	5 Feet
Slope covered	5 Feet
Grey shale	10 Feet
Glen Dean Limestone	

The Leitchfield Formation commonly weathers to a clayey soil which is eroded rapidly and consequently its slopes are steep. The clayey soil does not absorb water readily and dries out rapidly, frequently cracking open in the process. These steep slopes and poor soil form land of little value for agriculture and the outcrop of the formation is overgrown in most places by scrub timber and brush.

Stratigraphic Relations. It has been stated previously that the presence or absence of an unconformity at the base of the Leitchfield Formation is undetermined. No certain evidence of such an unconformity has been observed although the sharp change in the character of the sediment and the variation in

thickness of the Glen Dean, particularly in the northeastern part of the county, are somewhat suggestive.

The Lietchfield is overlain unconformably by the Pennsylvanian sediments. The unconformity which separates the two Carboniferous Systems is a highly conspicuous stratigraphic feature and represents not only a possible sedimentary hiatus but also a period of extensive erosion during which time the entire thickness of the Leitchfield, Glen Dean, Hardinsburg, Golconda and probably the Cypress were locally removed producing a relief of over 300 feet.

Correlation. The basal sandstone member where it is present in the Lietchfield Formation is believed to be the equivalent of the Tar Springs Sandstone named by Owen in 1857[27] from Tar Springs three miles south of Cloverport, Breckenridge County, Kentucky. The Tar Springs Sandstone is recognizable as a distinct formation in southern Illinois, southwestern Indiana and western Kentucky. In the region about Edmonson County, however, and along the eastern order of the Western Coal Field the formation loses its individuality, becomes more or less shaly and at many localities cannot be recognized at all. The formation is unknown in the region still farther south and east.

With the exception of the Tar Springs Sandstone Member no part of the Leitchfield can at this time be correlated with the smaller units of the Upper Chester as known farther to the west. It is possible, however, that future detailed surveys connecting Edmonson County with Caldwell and the adjoining counties of western Kentucky will make possible a better interpretation of the equivalents of the various parts of the Leitchfield Formation. Paleontologically the Upper Chester beds are all somewhat similar and at present but little can be determined from the fossils.

The Leitchfield Formation is considered as including all beds of Upper Chester age so far as they are represented in this part of Kentucky. In southern Illinois and western Kentucky, the Tar Springs Sandstone, Vienna Limestone, Waltersberg Sandstone, Menard Limestone, Palestine Sandstone, Chlore Limestone, Degonia Sandstone and Kinkaid Limestone constitute the Upper Chester and the equivalents of some or all of these

[27] D. D. Owen: "Second Report of the Geological Survey in Kentucky." (1857), p. 87.

may be present in the Leitchfield. In Breckinridge, Grayson, Hart and Edmonson Counties the Buffalo Wallow of Butts with the addition of the Tar Springs Sandstone at the base is the equivalent of the Leitchfield. In Indiana it is to be correlated with the Tar Springs Sandstone, Siberia Shale and Buffalo Wallow. The Leitchfield is probably the equivalent of the Pennington Shale of central Tennessee and eastern Kentucky.

Paleontology. The shales of the Leitchfield Formation are apparently entirely barren of fossils. Some of the thin limestones, particularly those which occurs near the base, are abundantly fossiliferous. The following lists are characteristic of the fauna occurring in these beds:

NEAR BASE OF LEITCHFIELD FORMATION
MOUTH OF LITTLE BEAVERDAM CREEK

Pentremites sp.
Pterotocrinus cf. *depressus* L. & C.
Tabulopora tuberculata (Prout)
Fenestella sp.
Polypora complanata Ulrich
Streblotrypa nicklesi Ulrich
Heliotrypa bifolia Ulrich
Orthotetes kaskaskiensis (McChes)
Spiriferina spinosa (N. & P.)
Spirifer increbescens Hall
Eumetria costata (Hall)
Cliothyridina sublamellosa (Hall)
Composita subquadrata (Hall)
C. trinuclea (Hall)
Leda sp.
Aviculopecten sp.
Phillipsia sp.

WARREN COUNTY
LEITCHFIELD FORMATION 3 MILES NORTH OF RICHARDSVILLE

Meekopora clausa Ulrich
Tabulopora tuberculata (Prout)
Archimedes swallowanus Hall
A. sublaxus Ulrich?
Lyropora sp. (base)
Septopora subquadrans Ulrich
Rhombopora sp.
Streblotrypa subpinosa Ulrich?
Heliotrypa bifolia Ulrich

Orthotetes kaskaskiensis (McChes)
Spiriferina spinosa (N. & P.)
Spirifer increbescens Hall
S. leidyi (N. & P.)?
Eumetria costata (Hall)
Composita subquadrata (Hall)

CHAPTER VII.

STRATIGRAPHY—ROCKS EXPOSED: PENNSYLVANIAN SYSTEM.

Mississippian-Pennsylvanian Unconformity

Throughout the entire Mississippi and Ohio Valleys the strata of Mississippian and Pennsylvanian age are separated by an important erosional unconformity. In Edmonson County the relief of the Mississippian surface exceeds 300 feet and the

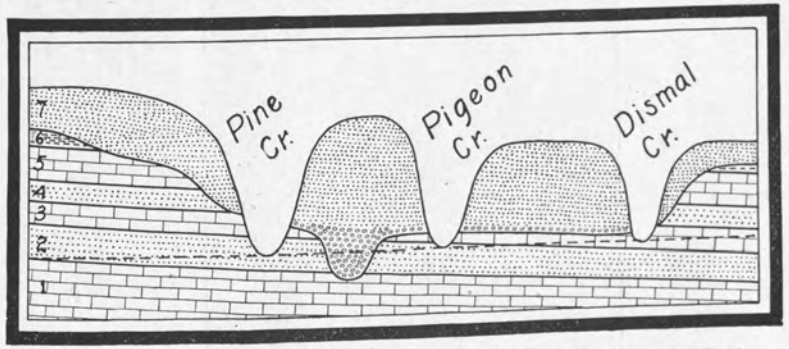


FIG. 39. SECTION SHOWING FOSSIL STREAM CHANNEL.
Formation Key: 1. Renault-Paint Creek Ls.; 2. Cypress ss.; 3. Golanda Ls.; 4 Hardinsburg ss.; 5. Glen Dean Ls.; 6. Leitchfield Fm.; 7. Pottsville ss.

Pennsylvanian beds rest at different localities upon the Leitchfield, Glen Dean, Hardinsburg, Golconda, Cypress and probably the Renault-Paint Creek formations. The erosion which took place before the Pottsville was deposited was performed largely by a westwardly flowing river, the conglomerate filled channel of which is to be plainly observed crossing Nolin River between Pine and Dismal Creeks.

The deepest portion of the channel of this fossil stream occurs between Pine and Pigeon Creeks where the massive basal Pottsville sandstone cuts through the Golconda Limestone and is exposed at low water level on Nolin River. This is the only locality where such deep erosion may be observed. Both to the north and south the erosion was less and less pronounced and the various Chester formations make their appearance much in the nature of huge steps. To the south the Pottsville cuts through

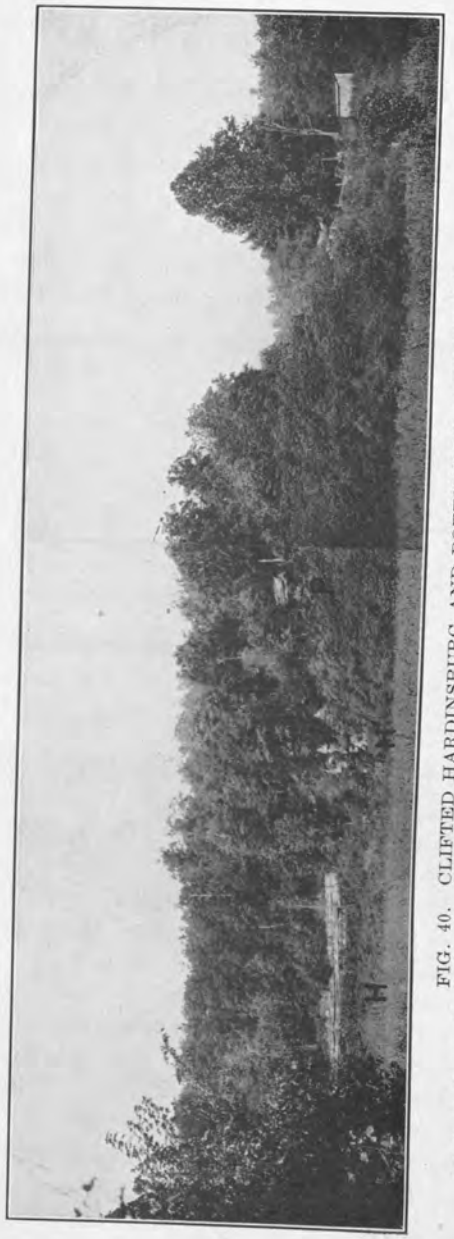


FIG. 40. CLIFTED HARDINSBURG AND POTTSVILLE SANDSTONES.
View of the end of the spur which stands between Dismal Creek and Nolin River as seen from the southwest. H and H' are bluffs of massively developed Hardinsburg Sandstone and P is an exposure of the basal sandstone member of the Pottsville. In this spur the Pottsville rests successively upon the Leitchfield, Glen Dean, Hardinsburg and Golconda formations and here is to be observed an excellent section of the northern side of the great channel which occurs at the Mississippian-Pennsylvanian unconformity. To the left beyond the edge of the picture the Pottsville rests upon the Leitchfield, at H the Leitchfield has been cut out and the Pennsylvanian sandstone lies directly upon the Glen Dean, at H' the Glen Dean is gone and it directly overlies the Hardinsburg while near the shed at the right Pottsville outcrops low down upon the hillside and without doubt rests upon the Golconda.

the Glen Dean upon the south side of Pine Creek and to the north at the end of the spur which separates Dismal Creek from Nolin River. Similar situations also exist near the head of First Creek, upon the west side of the Wet Prong of Buffalo Creek southeast

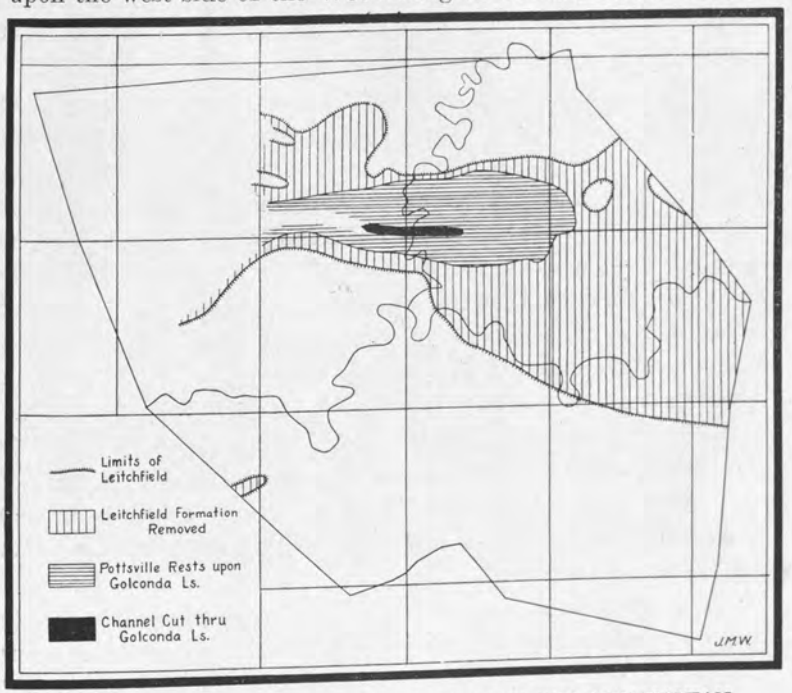


FIG. 41. MAP SHOWING MISSISSIPPIAN-PENNSYLVANIAN UNCONFORMITY.

of Ollie and the first large tributary hollow of Brier Creek from the south. Throughout the whole valley of Bylew Creek the Pottsville rests upon the Golconda while at the heads of Wolf and Brier Creeks this formation lies upon the Glen Dean. The erosional step-down therefore between the Glen Dean and Golconda must occur somewhere beneath the ridge upon which are situated Straw and Sanders Store.

West of Nolin River this step-down has not been observed but from the manner in which the Glen Dean disappears in Beaverdam Creek and Gulf Hollow the southern edge of the old channel must be close by. The westward course of the stream which carved this ancient channel is demonstrated by the deepen-

ing of the channel in this direction. East of Sanders Store the erosion along this main channel has nowhere extended below the Glen Dean Limestone while five miles to the west on Nolin River the Golconda has been cut through and the Pottsville probably rests upon the Renault-Paint Creek Limestone below, making a stratigraphic drop of something like 160 feet.

Besides the main pre-Pottsville valley two subsidiary channels are known. One is shown in the valley of Wolf Creek southeast of Hester School where the Pottsville is dropped down through the Glen Dean and probably rests locally upon the Hardinsburg Sandstone. Post-Mississippian erosion has cut deeply into if not completely through the Glen Dean Limestone one-third of a mile above the mouth of the tributary of Dog Creek, which drains the country east of Sanders Store. This is without doubt a continuation of the channel observed on Wolf Creek. The other is to be seen along Bear Creek between Mill and Nappers Branches. Here the channel is cut in the Leitchfield and the Pottsville probably rests upon the Glen Dean although this formation is not exposed. These subsidiary channels are undoubtedly connected with the main one but their exact relationship cannot be observed.

Conglomerates occur both in the main channel on Nolin River and in the smaller one on Bear Creek. The pebbles occurring at the former locality attain a maximum size of nearly three and one-half inches and the heavy conglomerate here is separated sharply from the massive sandstone above. The pebbles in the Bear Creek Channel are much smaller, one-quarter inch being the average diameter at this locality.

The shaly Leitchfield Formation has been swept away for varying distances both to the north and south of the main channel and the Pottsville rests unconformably upon the Glen Dean Limestone. The area over which the Leitchfield has been completely removed is greatest to the east and south of the deep channel in the region east of Nolin River.

What may be another small subsidiary channel occurs near the southwestern boundary of the county. Here the Leitchfield is absent over a restricted area in the neighborhood of the Sand Hill Fault. Another somewhat similar situation occurs upon the

north side of Brier Creek just north of Nolin School where the Pottsville rests directly upon the Glen Dean.

It is interesting to note that throughout that portion of Edmonson County where the Mississippian-Pennsylvanian unconformity is most extensively developed, the uppermost Mississippian formation is almost everywhere limestone. The Pottsville was deposited upon great flats developed upon both the Glen Dean and Golconda Limestones but where the step-down occurs between these two formations the intervening Hardinsburg apparently stands as a rather steep slope and the river which at one time occupied this channel probably cascaded down small waterfalls from the Glen Dean to the Golconda and from the Golconda to the Renault-Paint Creek. This condition is entirely at variance with that which prevails today throughout that portion of the county where the Chester formations are extensively exposed. Under present conditions sandstone is much more resistant to erosion than is limestone and not only are the ridges capped by this type of strata but many of the streams flow over beds cut in sandstone. This is true of each of the tributaries of Nolin River which join it from the east, these streams being

FIG. 42. A NOLIN RIVER TRIBUTARY.

View looking up Dismal Creek from the small bridge which crosses near its mouth. H, H' and P are the same exposures shown in Figure 27 while G is the Golconda limestone which outcrops low down upon the hillside.

most comparable on a small scale to the river which cut its channel before the deposition of the Pottsville.

The conditions which prevailed therefore during the time when this channel was excavated must have been radically different from what they are today. In the present erosional development the limestones are without any doubt attacked to a greater extent by solution than by mechanical wear and this accounts for their being less resistant than sandstone, which is practically unsusceptible to solution. In view of these facts the most logical conclusion is that the erosion which took place before the deposition of the Pottsville was rapid. A large and swift stream of water amply armed with cutting material in the form of sand and gravel would probably be able to remove a moderately well cemented sandstone more rapidly than a compact limestone. In this way the sandstone would be stripped rapidly from the underlying limestone and the stream would make its bed upon this formation. When the first limestone was cut through, the next underlying sandstone would have been actively eroded and a gorge speedily cut. The valley would then have been widened by lateral erosion of the sandstone and undermining of its protecting limestone cover.

Certain other features give strength to the theory of the rapid excavation of the pre-Pottsville channel by a large flow of water. Along Nolin River where the deepest erosion is to be observed the channel is narrowest. To the east the scoured surface upon which the Pottsville rests becomes over twice as wide as is plainly shown in figure 41. There is an apparent inverse relationship between the width of this old channel and its depth. In the neighborhood of Stockholm and Cade, which are situated in the broad shallow portion of the channel, the Pottsville rests upon the Glen Dean Limestone, the thickness of which is here uniformly about 20 feet. The normal thickness of this formation as determined from its complete exposure in various parts of the county is near 60 feet and without doubt its comparative thinness in the area mentioned is due to the erosion which preceded the deposition of the Pottsville.

Quite similarly the thickness of the Golconda upon which the Pennsylvanian beds lie in the valley of Bylew Creek has been reduced to 15 feet from its original thickness of over twice this

amount. The constriction of this channel which occurs in the direction of its deepest erosion together with the wide and deeply though rather uniformly scoured limestone surface, upon which the Pottsville lies in the eastern part of the county point toward the erosion of this channel by a flood of water which entered the county in a shallow stream perhaps six miles in width but which was concentrated farther to the west in the deep channel which is to be observed along Nolin River.

The flood which ushered in the Pennsylvanian deposition in this area may have followed a drainage line developed upon the Mississippian land surface, but the erosion which took place along this line was almost entirely the work of the Pennsylvanian torrent. This channel could not have been produced by a normal stream of the old land surface for a member of reasons. The gradient is locally much too steep for a normally developed stream and the valley is much too wide for such a steep gradient. No normal tributary valleys have been recognized. If present these would be deeply entrenched and would constitute conspicuous features. During the time required for the normal development of a valley 200 feet deep erosion would probably have removed to a large extent the unresistant Leitchfield Formation which formed the surface of the pre-Pennsylvanian land. This formation is, however, almost universally present up to the edge of the channel, and elsewhere, although its surface is uneven, few channels have been cut down to the Glen Dean Limestone. It therefore seems probable that the normally developed streams which drained this area flowed through comparatively shallow valleys developed almost entirely in the Leitchfield shales and probably nowhere eroded much below the top of the Glen Dean Limestone.

If this ancient channel which crosses Edmonson County were cut by a flood of waters bursting suddenly upon it from the east, as the evidence seems to indicate, the cause must be searched for in this direction. It is known that the basal Pennsylvanian beds throughout the Ohio and Mississippi Valleys become progressively younger as they are followed in a westerly direction. These sediments and all the rest of later Pennsylvanian age were derived from an extensive mountain region which rose above the present Appalachian Piedmont plateau and

of which no remnants other than the roots of the mountains now remain. The first sediment brought down from this area was deposited at the foot of the mountains and an alluvial plain was built up by the deposition of more and more material upon and extending out farther to the west than the earlier deposits. This advancing alluvial plain rapidly extended westward into the Appalachian Trough which lay between the mountains and the Cincinnati Arch. The river which flowed southward through this trough to the Gulf of Mexico was unable to cope with the vast amount of debris brought down from the mountains and it was crowded farther and farther to the west.

Sedimentation continued in the Appalachian Trough until it was either completely filled to the level of the saddle which existed upon the Cincinnati Arch between the Cincinnati and Nashville Domes, or else more rapid deposition took place in the southern portion of the trough, the course of the river which drained it being dammed, as a result of which the waters backed up until they sought an outlet westward across the saddle on the anticline. In either case the waters gathered from a considerable area in the mountains to the east suddenly burst across the lowest point on the Cincinnati Arch. The rapid westward advance of the Pennsylvanian sediments coupled with a gradual submergence of this area, brought the erosion of the Mississippian beds to a stop and the channel which had been developed became filled with gravel and coarse sand.

This erosion channel which crosses Edmonson County is without doubt the western extension of the Pennsylvanian filled channel which has been recognized extending across Hart County and along the Larue-Green and Marion-Taylor County lines for a distance of 40 miles to the east.[1]

Pottsville Series.

Distribution. All of the Pennsylvanian beds present within Edmonson County belong to the Pottsville or basal series of this system and are probably to be referred in their entirety to Glenn's, Caseyville and Tradewater formations of the more western Kentucky counties. They occur at the surface over about one-half of the total area of the county. Throughout the Hilly

[1] W. G. Burroughs: "A Pottsville-Filled Channel in the Mississippian." Ky. Geol. Surv., Ser. 6, Vol. 10 (1923), pp. 115-126.

Country and the Sunfish Area west of Bear Creek, Pottsville beds are the only ones exposed, over the remainder of the Hilly

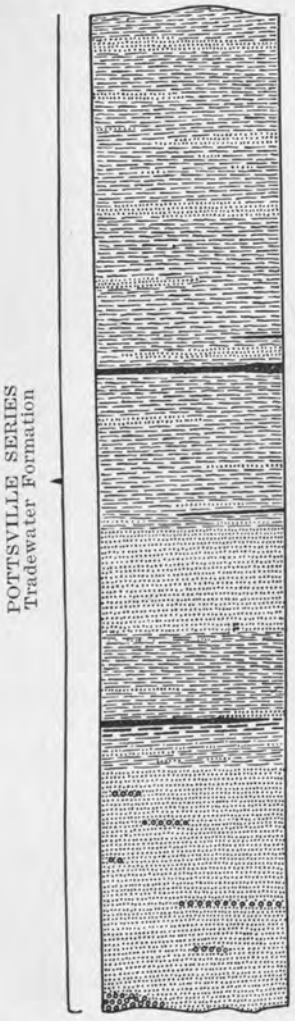

POTTSVILLE SERIES
Tradewater Formation
Shale, sandy shale and shaley sandstone.
This part of section poorly exposed.
Thin local coal.
Persistent coal in northwestern part of county.
Bluish gray shale and thin sandstones.
Thin local coal.
Bee Spring Sandstone.
Characteristically developed in north central part of county.
Dark grey shale.
Main Nolin Coal.
Rather persistent.
Massive basal "conglomerate" sandstone.
Present in Pennsylvanian channel and to the south; largely absent to the north.
Massive conglomerate locally present at base.

FIG. 43. GENERALIZED SECTION OF THE PENNSYLVAIAN STRATA IN EDMONSON COUNTY.

Country to the south and east they constitute the grater part of the hills and ridges which rise above the Mississippian beds exposed along the valleys, and within the Knob Belt numerous

isolated outliers occur capping the small steep hills and narrow ridges.

Thickness. The total thickness of the Pennsylvanian beds present within the county is rather difficult to estimate but is probably about 450 feet.

Topography. The topography developed upon the Pottsville strata is in general of a rugged character. The alternating sandstones and less resistant beds are ideally disposed to produce steep slopes interrupted by gentle terraces and culminating in rather flat topped hills. The thick and massive sandstones present in the lower part of the section at many places stand in vertical cliffs or produce steep slopes strewn with sandstone boulders. The shaly beds in the upper part of the section produce more uniform slopes, standing at steep angles, however, and rising abruptly from the valley flats. The valleys, cut in the lower sandstones are deep and narrow and some of them are bounded by sheer canyon-like walls. Cirque-like amphitheaters are not uncommon in the upper parts of these valleys, many of which are totally unscalable and after rains produce waterfalls 50 or even 60 feet in height. The larger valleys developed in the higher beds are greatly in contrast to those just described, being wide and open although bounded by steep hills. The smaller hollows and ravines of the upper shaly beds are commonly V-shaped notches which descend rapidly with steep gradient to the larger streams below.

Generalized Section. Sections of the Pottsville at various localities in Edmonson County are quite different as the result of pronounced lateral variation and until more detailed studies have been made correlation seems almost impossible. The generalized section which accompanies this chapter has been so arranged that this series of beds can be subdivided for purposes of description. The thickness and character of each member is, however, quite variable and at many localities the various divisions cannot be recognized at all.

Lithologic Character. The lowermost member of the Pottsville is a massive coarse grained sandstone conspicuously cross-bedded in many parts. It achieves its maximum development within the borders of the Pennsylvanian filled channel, its maximum thickness being about 250 feet, and it is particularly well

exposed in vertical cliffs at Dismal Rock and along the valley of Bylew Creek. North of the old channel this member is generally entirely absent. Sandstones occur locally at the base of the Pottsville which may be referred to it but they are comparatively thin and not conspicuous. This lowermost sandstone member consistently overlies the Mississippian beds south of the old channel, but its thickness is considerably depleted, 40 to 60 feet being the limits of its general development in this part of the county. Good exposures occur along the road just north of the Brownsville Ferry at Indian Hill and also along Gulf Hollow.

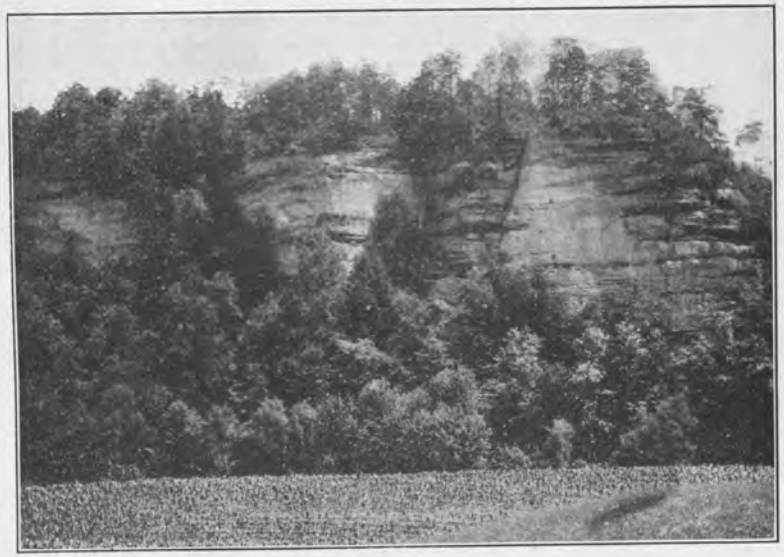


FIG. 44. DISMAL ROCK.
This massive basal Pottsville sandstone is shown as it is developed at the north side of the old Pennsylvanian filled channel. Another view was shown as a frontispiece illustration in one of the early geological reports of the David Dale Owen Survey in 1856.

The lowermost massive sandstone of the Pottsville is of rather uniform character throughout the area where it is present. The exposed surfaces are dark brownish in color and not uncommonly case-hardened or covered with a coating of limonite. Fresh surfaces are lighter brown than the outcrops and almost pure white beds are locally present. The sandstone to a large extent

is composed of one steeply crossbedded layer above another varying in thickness up to a general maximum of three or four feet. Sand grains of widely divergent sizes occur in adjoining layers, but most of the strata are composed of coarse angular quartz grains rather firmly cemented together. Rounded pebbles of

FIG. 45. INDIAN HILL.
The view is from the southwest. Bluffs of the massive basal sandstone of the Pottsville rise abruptly above the slope which is developed upon the Leitchfield Formation.

white or slightly stained vein quartz occur throughout this member. They are locally quite abundant and at a few localities form massive deposits, evidently filling ancient stream channels. In size they vary from two and one-half to one-quarter of an inch or less although by far the greater number average from one-half to three-quarters of an inch in greatest diameter.

Above the lower massive sandstone occurs a shale zone which varies from 50 to 100 feet in thickness in those parts of the country where it can be recognized. The Main Nolin Coal occupies a position in the lower part of this zone. North of the old Pennsylvanian filled channel these shales immediately overlie the Mississippian and in this part of the county it is a difficult if not impossible matter to locate accurately the boundary between these two systems. These Pennsylvanian shales are well exposed in the upper parts of a number of the hollows which head upon either side of the ridge north of Bee Spring. Here they are

dark grey in color, apparently free from sand, and there is little in their character to suggest that they belong to the Pottsville rather than the underlying Leitchfield Formation. To the east, south and west, however, these beds change in character, become quite sandy and take on a definitely Pennsylvanian aspect. Both to the east and west they become a lighter grey or brown color, are rather sandy in certain parts and interbedded with shaly sandstones or thin but more massive beds and contain here and there layers formed of tightly fitting angular limonite concretions. To the south these shales grade into still more sandy beds and south of Sweeden this interval is difficult to distinguish from the sandstones which both over and underlie it.

The Main Nolin Coal is rather uniformly present in the lower portion of this shale zone except in the region south of Sweeden and east of Segal, where there is no indication of its presence. The extent of the coal may be traced by means of old diggings throughout the valleys of Dismal Creek, several of the tributaries of Bear Creek which head upon the west side of the ridge, also along Beaverdam Creek and its tributaries in the neighborhood of Grassland, the upper part of Gulf Hollow, southwest of Segal and several localities west of Bear Creek. Outcrops of a coal which is probably to be correlated with this occurs east of Nolin River at several localities along Longfall Creek, in Brier Creek below Straw and also in the neighborhood of Ollie. The Main Nolin Coal is also known to occur south of Green River upon both sides of Little Beaverdam Creek. This is the most important coal in Edmonson County and in general maintains a rather uniform thickness of from two and one-half to three and one-half feet.

This coal is usually overlain by a foot or so of black coaly shale. In the bed of Sycamore Creek almost due south of Bee Spring a band of clay ironstone concretions occurs a few feet above the coal. The concretions are of rounding irregular shapes and are encrusted with scales of limonite. Their dark gray dense interiors contain streaks and cavities filled with some white substance and here and there occur darkly glistening clusters of sphalerite crystals.

The shale zone containing the horizon of the Main Nolin Coal is succeeded by a sandstone which is commonly referred

to as the Bee Spring Sandstone. This member is most conspicuously developed in the neighborhood of Bee Spring and along the ridge to the north. It is a massive sandstone similiar in many ways to the lowermost sandstone member described above and in the district of its characteristic development varies between 40 and 60 feet in thickness. It is brown, coarse grained, crossbedded sandstone and locally it is a conspicuous cliff former. On the whole, however, it is less massive than the lowermost Pottsville sandstone and it also differs from this in the general absence of the rounded quartz pebbles which are so common below.

West of Bear Creek the Bee Spring standstone loses its massive character and is represented by a series of more thinly bedded and finer grained sandstones which locally attain a thickness of nearly 90 feet. South of Bee Spring this member ceases to be conspicuous, grading laterally into softer and more thinly bedded strata not much different from the beds below. The sandstone becomes in part lighter in color while other portions assume a reddish tinge. More massive standstone is, however, locally present at this horizon south of Green River in the hills on either side of Little Beaverdam Creek.

Overlying the Bee Spring Sandstone occurs a series of shaly beds and shales with local massive but thin sandstone which constitute the remainder of the Pottsville section in Edmonson County. A thin coal varying from 0 to 14 inches in thickness occurs close to the base of these beds. This coal may be seen outcropping by the side of the ridge road half way between Bee Spring and the north county line, in the vicinity of Grassland, south of the Upper Morgantown Road one mile northwest of Steep Hollow School and at Segal. The coal which has been dug on a small scale just above the road one-half mile south of Big Reedy is probably also to be correlated with this horizon. At this latter locality a third coal occurs about 75 feet higher in the section which is persistent upon both sides of Reedy Creek and throughout the hills to the east, ranging in thickness at those places where it has been opened from 20 to 30 inches.

In the hills beween Bear and Reedy Creeks and south of Whetstone Creek the beds below the third coal mentioned above are largely grey to nearly black shales with local thin interbedded sandstones or zones of sandy shale. At some localities layers of closely interlocked limonite concretions occur as well as a few thin beds of clay ironstone. These latter appear red at the outcrops but fresh surfaces are dark grey and dense, and are composed of calcite, limonite and a large amount of admixed argilaceous material. They contain small clusters of yellow

FIG. 46. LOWER PENNSYLVANIAN CLASTICS.
Shaley sandstones of the Pottsville a little over one mile south of Sunfish. The bed marked by a cross is a clay ironstone layer.

pyrite crystals and also small woody fragments which resemble charcoal in both color and texture but are considerably harder. Locally small pockets filled with black manganese oxide are present.

Both to the north and east of the district described above the shaly beds overlying the Bee Spring Sandstone horizon become more sandy and beds of grey or brownish shale alternate with shaly sandstone.

The third Pottsville coal which is extensively present in the northwestern corner of the county is overlaid by a few feet of shale, above which generally occurs a somewhat massive brown sandstone about ten feet in thickness. Above this sandstone the beds are poorly exposed and the remainder of the Pennsylvanian section, which amounts to about 200 feet, cannot be observed in

any detail. A thin local coal is said to occur at a few places close above this sandstone, but no definite description can be given of the overlying beds. The character of the topography and the lack of outcrops, however, is almost certain evidence of the absence of any noteworthy sandstone members and it is probable that a series of shales, sandy shales and shaly sandstones succeed the beds which have been described above.

The most conspicuous feature of the Pottsville section in Edmonson County is the marked lateral variation, together with the absence of any horizons other than the coals which might be employed to separate these beds into smaller units. Local unconformities are not uncommon, particularly in the more sandy beds, and upon the whole this series bears the unmistakable earmarks of terrestrial sedimentation.

Paleontology. No invertebrate fossils have been observed in any of the Pennsylvanian beds of Edmonson County although boulders of residual iron ore at the Old Proctor Ore Bank are reported to have been highly fossilferous.[2]

Imperfect plant fossils usually in a carbonized condition are not uncommon in some of the shales. Some fairly good specimens were collected just below the Brownsville Road one and one-third miles south of St. John's Church. Impressions and casts of the stems of *Lepidodendron, Sigillaria* and *Calamites* occur in the more massive sandstones. The most numerous specimens of this type were observed south of Green River in the neighborhood of Wainfield School.

By far the most interesting evidences of life during early Pennsylvanian time are footprints preserved in massive sandstone in Grayson County a little over one mile southwest of Van Meter School and a like distance north of the Edmonson County line. This locality has been known locally for over 100 years and the neighbors call it the "Turkey Track Rock." The writer was conducted to the spot by Mr. J. C. Van Meter of Bee Spring, a former land surveyor, who has taken an active part in the investigation and development of the rock asphalt deposits of the district and who first saw these tracks 60 years ago. At the present time 15 prints are visible on a massive sandstone

[2] Moore: "Geology of the Nolin River District." Geol. Surv. Ky., 2nd Ser., Vol. 2, Pt. 2 (1877), p. 129 (51).

surface about 30 inches square while a single isolated print occurs some 10 or 15 yards to the south. Many more are said to have been observed in the past but many hundreds of ties have been hauled over this rock and doubtless a large number of the

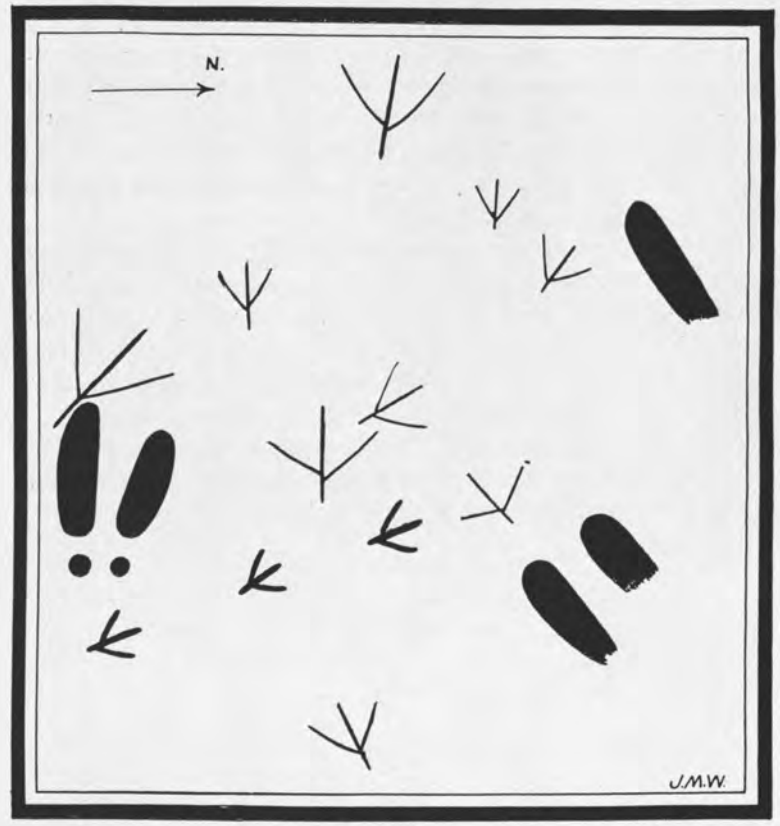


FIG. 47. FOSSIL FOOTPRINTS IN "TURKEY TRACK ROCK," GRAYSON COUNTY.

footprints have been obliterated. Although some of the tracks have been deepened and scratched out by means of a nail or other pointed instrument and counterfeits have been engraved upon other portions of the rock there can be no question concerning the genuineness of almost all of the tracks in this small area. Also some 20 odd years ago Mr. Van Meter, with the aid

of Evan Meredith, dug back under the soil for a considerable distance and found the tracks to continue beneath a cover two feet deep and upon which saplings and bushes were growing.

The footprints are of two types, the most abundant being rather similar in size and appearance to the tracks of a turkey and it is from these that the rock has received its name. These tracks are different sizes and were evidently made by several individuals. One series of three consists of prints considerably wider and more stubby than the others and may have been made by a different species from the others. Of the other type one perfect and two incomplete prints occur, the form of which is better shown in figure 47 than it can be described.

Although no suggestion can be offered at the present time concerning the exact nature of the animals which left these tracks, they are of great interest as this is the only known occurrence of Pennsylvanian footprints in this part of the United States. The form of the feet shows that the animals were adapted to living upon the land. Their reptilian morphology is therefore strongly suggested. It is consequently certain that these track imprinted beds were deposited either upon the land or else in very shallow water close to shore.

CHAPTER VIII.

STRATIGRAPHY—SURFICIAL DEPOSITS

Peneplain Deposits.

The remnants of the erosional flats which once were developed extensively throughout this part of Kentucky are preserved in Edmonson County largely through the great resistance to erosion which is characteristic of sandstone formations in a moderately humid climate. In Edmonson County the flat topped ridges and the gentle slopes which are present high above the present drainage lines are developed for the most part directly upon Cypress, Hardinsburg and Pottsville sandstones. Locally, limestone or shale as in the Knob Belt and some portions of the Hilly Country are the uppermost bed rock but they owe their preservation at these altitudes in most cases to an immediately underlying sandstone which has resisted erosion along the sides and at the heads of the valleys.

Residual soils developed upon sandstone strata might logically be expected to be of a very sandy nature. Even though a considerable amount of fine residual material was present the natural tendency would be toward the removal of a much larger proportion of this than of the sand and the soil remaining would become progressively more and more sandy. This result might well be accomplished through either the agency of wind or water, each of which in moderate amount is capable of carrying suspended dust and silt but not sand. In view of this the absence of extremely sandy soil from most of the level and gently sloping uplands is rather striking. In many places these upland soils are largely composed of fine almost impalpable dust which when dry is light colored and nearly white and is raised in clouds from the roads by every passing vehicle. This material is quite similar both in texture and color to the surface soils which are present upon some portions of the modern flood plains of the major streams in this part of Kentucky, as for example the Green and Barren Rivers. This similarity of the soils of the ridges and elevated gentle slopes of Edmonson County with that present

upon the modern alluvial flats, and its presence upon surfaces which are known from their position and the physiographic history of the region to have been base-leveled makes almost certain the conclusion that they are of alluvial origin and were deposited upon these ancient flats during Tertiary times.

On the north side of the Lower Morgantown Road one mile west of Steep Hollow School near the head of Honey Creek low alluvial terraces are present at an elevation of a little over 600 feet. It is probable that these terraces which rise about four feet above the modern narrow alluvial flat represent the surface of the old 600 foot erosion level at this locality.

No gravels of the Lafayette type have been observed within Edmonson County. No material capable of producing such gravels is immediately at hand and it is probable that no such gravels were deposited within this territory.

River Terraces.

Terraces rising six to eight feet above the level of the present flood plain of Green River are preserved at several localities. Examples may be observed upon the north side of the river at the Brownsville Ferry. These terraces probably represent the level of the flood plain as it existed late in the Pleistocene at the time when the large backwater lake occupied the lower part of the Green River Valley. Terraces of a similar nature are locally present along Barren River near Bowling Green.

River Gravels.

Water worn gravels are not commonly observed along the valleys of the major streams of Edmonson County above the level of their present channels. Dr. L. C. Glenn reports having seen some on the north side of Green River at Houchins Ferry, but their absence generally is quite notable. In Warren County, however, gravel occurs upon the west side of Barren River one mile north of Bowling Green at an elevation of some 60 feet above the present level of the river. The pebbles are commonly less than two inches in major dimension and although rather flat are well rounded upon their corners and edges. Three miles west of this locality an eliptical mound stands upon the flood plain

of Barren River which is apparently made up of gravel of a similar nature.

One small deposit of gravel in Edmonson County deserves mention although its origin is uncertain. This deposit occurs one-quarter of a mile south of Red Hill School by the side of the secondary road which leads wesward from the main ridge road into one of the forks of Bullock Branch.

The gravel is composed largely of well rounded limestone pebbles which vary in size up to a maximum of two and one-half inches in diameter, while pebbles of chert and sandstone are also present in lessor abundance. Some of the limestone pebbles are of a type quite different from any of the limestone which is exposed in this vicinity and the situation of the deposit well above the base of the Pottsville proves conclusively that they were dropped here by running water after having been transported for some considerable distance. It seems possible that they may mark the ancient course of either Green River or Bear Creek, which, it appears, flowed at one of its earlier stages in a couple of large meanders along what is now the course of Bullock Branch and Caney Hollow.

Alluvium.

Some alluvial material is present along the courses of all of the small streams in Edmonson County, but flood plains or valley flats are absent except along Green and Nolin Rivers and Bear and Reedy Creeks, where typical flood plains are developed. Due to the steep V-shape of the valley they are in most places quite narrow and are not uncommonly present upon only one side of the stream. These deposits are composed of silts and muds with the admixture of a considerable amount of sand. In contrast to this, the alluvium of the smaller tributaries is more sandy and contains both angular and rounded pebbles derived from the immediately adjacent formations.

CHAPTER IX.

STRUCTURAL GEOLOGY.

Edmonson County is situated upon the west flank of the Cincinnati Arch just south of the axis of the syncline which noses in between the Nashville and Cincinnati Domes. In a general way, the strata strike northeast-southwest and dip to the northwest at the rate of about 30 feet to the mile.

Structural Contour Map.

The structural contours overprinted on the geological map of Edmonson County and shown here within reduced outline

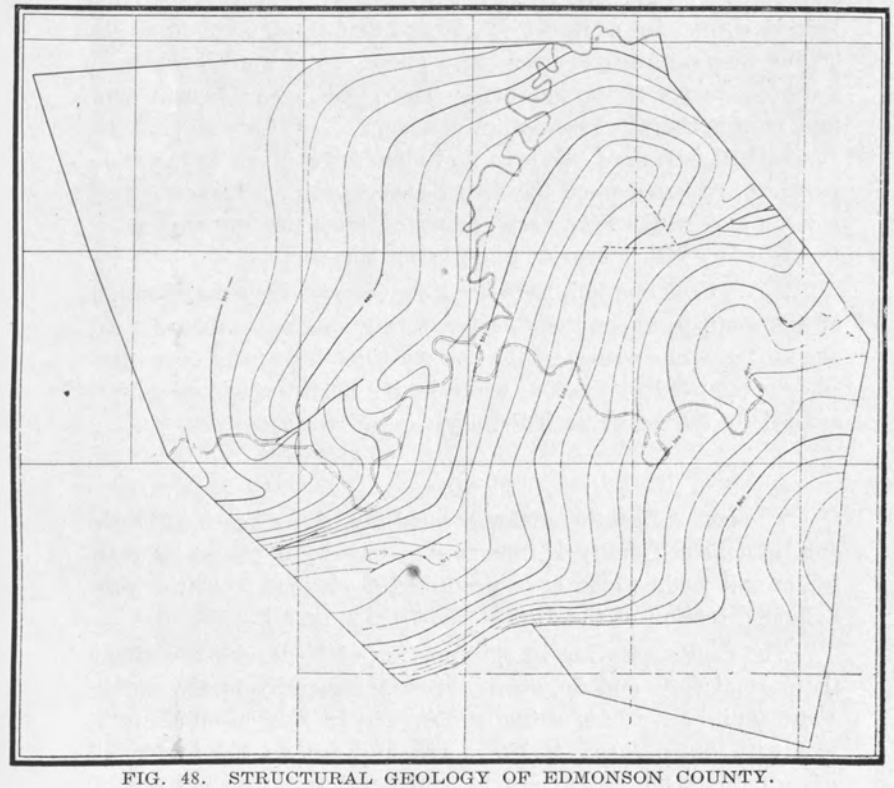


FIG. 48. STRUCTURAL GEOLOGY OF EDMONSON COUNTY.
The contours are drawn on top of the Cypress sandstone.

are based upon aneroid elevations taken at many points upon the contacts between the various Chester formations. The contoured horizon is the top of the Cypress sandstone, chosen because it is one of the most widely distributed horizons within Edmonson County and because it is readily recognized by innumerable springs which issue from below the Golconda Limestone. The contour interval is 25 feet, this being considered the minimum interval that may be employed with reasonable accuracy. As presented the structural contour map has been constructed by compilation from a series of maps, each of which was based upon a single horizon, these horizons including the contacts between each two adjacent Chester formations from the base of the Cypress to the base of the Leitchfield and also two higher horizons within the Leitchfield Formation itself. Most of the minor structural irregularities apparent upon these various maps have been smoothed out as it was considered that many of them might be due to errors in measurement. These errors were occasioned by the vagaries of the aneroids. The resulting structural contour map is therefore somewhat generalized. On account of the generalized nature of this map no indication is given as to which portions are based upon the direct observation of the contoured horizon and which have been computed from the observed position of other either over or underlying horizons.

Structural contours have been drawn over only that portion of the county where the Chester formations are exposed. In the southeastern corner of the county these beds have been completely removed by erosion, while in the northwestern part they are wholly buried beneath Pennsylvanian strata.

Faults.

The general gentle northwestward dip of the strata throughout Edmonson County is interrupted in several places by both faults and folds which have produced deviations from the prevailing direction of the dip.

The faults occuring in this portion of Kentucky are all of the normal type and the down throw is generally to the north. Four faults have been actually observed in Edmonson County, two with down throw to the north and two to the south, all of which trend in a nearly northeast-southwest direction.

Aside from these four, the presence of a fifth fault is fairly certain and the existence of a sixth is strongly suspected.

Sand Hill Fault. The Sand Hill Fault extends from a point a little over one-half mile south of Cedar Valley School in War-

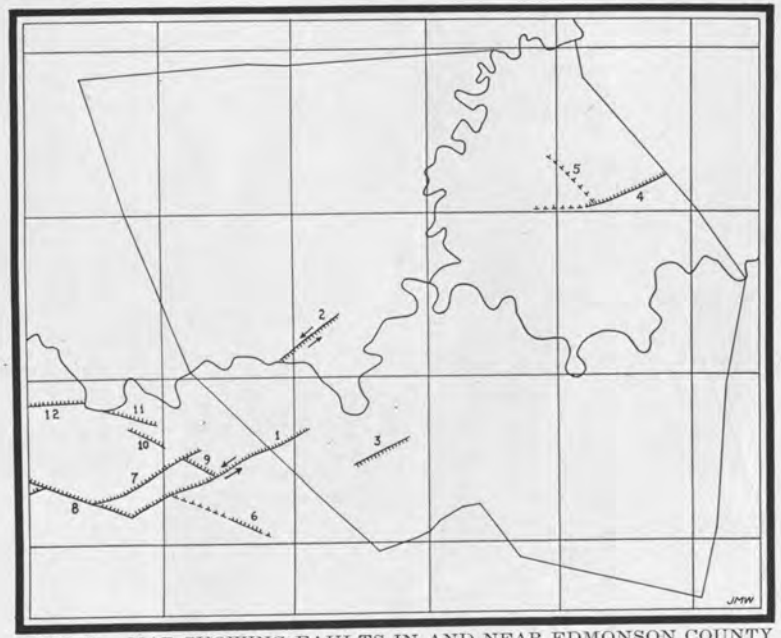


FIG. 49. MAP SHOWING FAULTS IN AND NEAR EDMONSON COUNTY
Fault pattern key: 1. Sand Hill Fault; 2. Honey Creek Fault; 3. Alexander Creek Fault; 4. Dog Creek Fault; 5. Straw Fault; 6. Dripping Springs Fault (hypothetical).

ren County, northeast through the hamlet of Sand Hill, crosses into Edmonson County and plays out about one-half mile southeast of Wainfield School. Its total length is seven miles, about one and one-half of which lies within Edmonson County. This fault is one of those with the down throw upon the north. At the Edmonson-Warren County line the displacement is about 140 feet but it diminishes rapidly to the east.

Slickensides developed by this fault are well shown in a sink hole just east of Sand Hill. Here the Glen Dean is faulted down against the Cypress, the displacement being about 150 feet. Solution acting along the fault plane has produced a line of sink holes more or less in the form of a valley which extends in a northeastward direction. The second sink hole east of Sand

Hill has been developed by the solution of the Glen Dean Limestone upon the north side of the fault and the Cypress Sandstone forms the southern wall. This sandstone surface had been indurated almost to a quartzite and grooves are well preserved

FIG. 50. A CHESTER FAULT.

Oblique view of slickensided Cypress Sandstone one-quarter mile northeast of Sand Hill in Warren County. Here the Sand Hill fault has dropped the Glen Dean down against the Cypress and the fault plain has been exposed as the result of the formation of a sink hole in the limestone on the north side of the fault.

upon the slickensided surface. The fault plane is inclined 17° from vertical, the dip being of course to the north. The striations as viewed from the north dip toward the east at an angle of 67°.

Honey Creek Fault. The Honey Creek Fault extends northeast from Green River just west of Pittsburg Landing, crosses Crooked and Honey Creeks and probably plays out beneath the

hill which separates the valley of Honey Creek from Green River. This fault is about three miles in length, is of the normal type with the down throw to the south and has a maximum displacement of about 90 feet. It is well shown in the valley of Honey

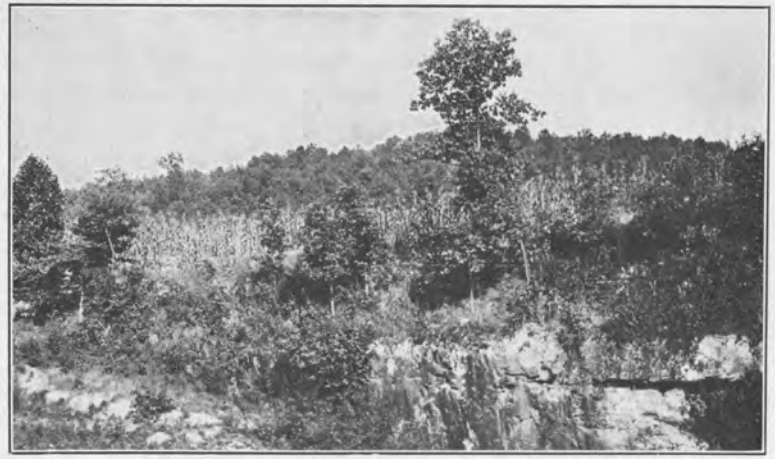


FIG. 51. SLICKENSIDED POTTSVILLE SANDSTONE

Which forms the southern side of a sink hole four-fifths of a mile northeast of Pittsburgh Landing. At this place the Honey Creek fault has dropped the Pottsville down against the Glen Dean and a sink hole draining down along the fault plain has developed in the limestone.

Creek just below the secondary road which crosses it in its upper part and also just east of the road which extends along the ridge between Honey Creek and the small hollow to the west. At this latter locality the Pottsville is faulted down against the Glen Dean and a sink hole has been dissolved in the limestone which drains down along the fault plane. Slickensided sandstone forms the southern side of the sink, the surface of which is plainly striated. The fault plane at this point is inclined 13° from vertical dipping to the south and the striations as seen from the north dip at an angle of 80° to the west.

Alexander Creek Fault. A fault with down throw to the south occurs near the house one-half mile east of Pine Grove School where the succession of Golconda over Cypress is repeated in a small hollow. This fault has not been located exactly either to the east or west of this point. The Cypress Sandstone exposed in the bed of Alexander Creek is much shattered and

steeply tilted. The maximum extent of this fault is probably about two and one-quarter miles and the greatest displacement cannot be more than about 50 or 60 feet.

Dog Creek Fault. A fault with down throw to the north has dropped the Pottsville down against the Glen Dean and Hardinsburg formations in the upper portions of a number of hollows east of Sanders Store which drain into Dog Creek. The throw of this fault cannot be closley estimated although it is probably not far from 100 feet at the Edmonson-Hart County line.

A small fault cutting the Pottsville with the down throw to the north is reported a short distance northeast of Ollie.[1] This may be a westward extension of the Dog Creek fault. If this presumption is correct this fault has an extension of some five milees within Edmonson County and without doubt continues for some distance into Hart County.

Straw Fault. The fact that the Golconda Limestone outcrops in the upper portion of Bylew Creek at about the same elevation as the Glen Dean at the head of Wolf Creek only a mile away necessitates the conclusion that a fault with down throw to the east cuts northwestward beneath the ridge which separates the heads of Wolf and Brier from Bylew Creek.

Warren County Faults. Of the numerous faults which have been recognized in northeastern Warren County only one deserves specific mention in this report. This fault (No. 6, see figure 49) extends from the Cypress capped upland to the lowland upon the south about midway between Sand Hill and Girkin. At this point its throw as recognized in the displacement of the Cypress Sandstone is about 40 feet, the down throw being to the north. Its trend is northwest-southeast but its extent has not been determined. Its direction is such that if it continued to the east it would pass along the edge of the Dripping Spring Escarpment, where this originates as a topographic feature two and one-quarter miles west of Boiling Spring School.

The general appearance of the Dripping Spring Escarpment is suggestive, as has been indicated, of its being in the nature of a fault scarp. Its sharp southern slope and the absence of any

[1] J. O. Bryant: "Economic Geology of a Portion of Edmonson and Grayson Counties." Ky. Geol. Surv., Ser. 4, Vol. 2, Pt. 1 (1914), p. 185.

projecting spurs and its gently curving form, which in part at least corresponds with the general direction of the faults of the region, point toward this conclusion. The rather unequal thickness of the Ste. Genevieve Limestone which appears to be present along the southern side of this ridge also seems to uphold this view. It is quite probable therefore that this fault recognized in Warren County does extend along the Dripping Spring Escarpment, cutting completely across the southeastern tip of Edmonson County. The reader will note, however, that no fault has been mapped along this line on account of the absolute lack of any specific evidence of faulting. If this displacement does exist the Ste. Genevieve is either faulted against itself or against the St. Louis and the difficulty with which these formations may be separated and the absence of good outcrops in this limestone country are almost insuperable obstacles in its determination.

Folds.

The faults and folds of Edmonson County are undoubtedly closely associated as regards their origin, most of the irregularities in the dip of the beds being due to neighboring faults. The faults are of short extent and where they play out the displacement is adjusted in small anticlinal noses or local monoclines with inclinations as much as six times as steep as the prevailing dip of the beds.

Dripping Springs Monocline. The steepest dips of more than local extent which occur within Edmonson County are present upon the Dripping Spring Monocline. This structural feature strikes parallel to a portion of the southern boundary of the county for a distance of four miles in a direction about 30° north of east, then swings east and loses its identity before reaching the eastern county line. West of Dripping Spring School this monocline plunges to the north with an inclination of about 200 feet to the mile. The dip gradually decreases, however, and is brought to a stop by a shallow structural valley which roughly parallels the Dripping Spring Escarpment.

About Alexander Creek Fault. A shallow synclinal basin occurs on the south side of the Alexander Creek Fault near its eastern extremity. A low anticline which is probably highest adjacent to the fault extends almost straight west to the county

line and is separated from the Dripping Spring Monocline to the south by a broad shallow synclinal basin.

Sally Branch Monocline. A monocline dipping to the north comparable in steepness to that which descends from the Dripping Spring Escarpment occurs about four and one-half miles northwest of this latter structure. The western portion of this monocline is split by the Sand Hill Fault and it is probable that the localization of steeper dips along this short belt is due to the playing out of the fault whose displacement is taken up by an increase in dip.

Green River Syncline. A small syncline plunging to the west extends from the southwest county line up the valley of Green River to Brownsville where it ends abruptly.

About the Honey Creek Fault. The Green River Syncline is bounded upon the northwest by the Honey Creek Fault. This fault splits an anticlinal nose diagonally, the western portion being on the north side while the eastern part is on the south side of the fault.

Maple Spring Terrace. A terrace formed by the convergence of two small plunging synclines, one from the west and the other from the north broadens out from a narrow anticlinal neck near Mammoth Cave and extends across Green River about Maple Spring School.

About the Dog Creek and Straw Faults. The displacement of the extension of the Dog Creek Fault west of the junction of the Straw Fault is probably small. The Straw Fault is apparently of the hinge type, its throw increasing from nothing at its northern end to a maximum amount at its southern extension. East of the junction of these two faults, therefore, the displacement of the Dog Creek Fault is equal to the combined displacements of the two faults. This situation has caused the strike of the beds to swing around through an angle of 180° and a half dome has been formed, the crest of which occurs near Straw Post Office. Drag along the eastern part of the Dog Creek Fault has produced a syncline upon its north side and a northward dipping monocline has been developed to the south.

Bee Spring Nose. A decrease in the rate of dip to the northwest of Bee Spring in connection with the half dome formed by

the Straw Fault has produced a broad anticlinal nose in the north central part of the county.

Mechanics of Deformation

The faults which occur in Edmonson County and the adjoining region immediately to the west are of a somewhat peculiar type. Most of them are short and play out gradually in each direction and both of the slickensides which were observed indicate that considerable lateral movement has taken place. A diamond shaped pattern resulting from the intersection of two systems of faults is clearly evident in northeastern Warren County.

Although a study of these faults can produce no certain evidence concerning the mechanics of the forces which produced them a careful consideration of them is worth while on account of certain suggestions which result. Before entering upon such a consideration two assumptions must be made. These are: first, that the two main series of faults were formed contemporaneously and were therefore the results of the same forces. That this was actually the case is apparent from the relation of the Richardsville and Sand Hill Faults in Warren County which meet at an obtuse angle beyond which neither of them is known to extend. At this point the entire throw of one fault is transferred to the other, and obviously neither one could have been produced without the presence of the other. The second assumption is, that the lateral movement which is recorded on the slickensides of the Sand Hill and Honey Creek Faults was characteristic of the complete development of these faults. There is no absolute evidence to back up this assumption as the slickensides may record only the direction of the last movement which took place along these planes of fracture and earlier movements may have occured in other directions.

The short extent of the faults and the latteral movement known to have taken place along at least two of them together with the complete isolation of some of the faults suggest that these are perhaps only local developments along two systems of parallel, much more extensive fractures along which slight horizontal and lateral movement has taken place. Due to local

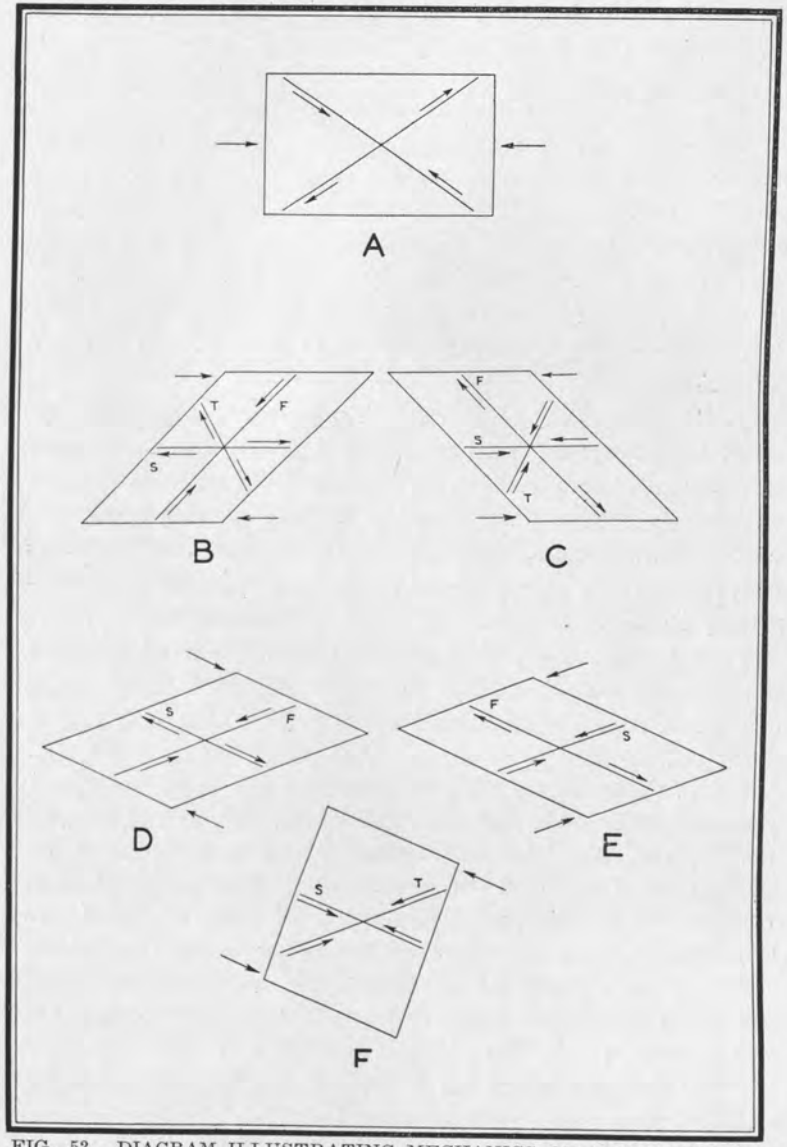


FIG. 52. DIAGRAM ILLUSTRATING MECHANICS OF DEFORMATION.

causes which are not understood vertical displacement may have occurred here and there along these lines of lateral movement.

The faulting cannot have been produced entirely by the subsidence of the Pennsylvanian bearing syncline to the north. If such was the case the down throw sides of all of the faults would lie to the north. Although this is the usual situation the displacement along the Alexander and Honey Creek Faults is reversed, the down throw being to the south.

Much experimental work has been conducted in an investigation of the interrelationship which exists between faults and the forces which produce them and this has resulted in a fairly clear understanding of such phenomena.[2] Normal faulting may be produced by either tensional or compressive forces. Tension results in a single system of parallel faults along which little or no lateral movement occurs, and with regard to the Edmonson County problem this case may be at once discarded. Compression produces two systems of parallel faults which intersect each other nearly at right angles and such a situation is at once suggested by the fault pattern shown in figure 46.

Compressional forces are of two types termed *non-rotational* and *rotational.* In the first case the opposing forces are directly opposite to one another while in the latter they are somewhat offset. Non-rotational compression produces two faults systems each of which extends at an angle of about 45° to the direction of thrust. These two systems do not intersect each other exactly at right angles, however, but the angles which are bisected by the direction of thrust are always somewhat acute while those at right angles to this direction are always somewhat obtuse.

Diagram A shows the orientation of faults produced by non-rotational compression together with the direction of lateral movement which would occur. A comparison of the lateral movement indicated along the north-east-southwest fault in this case with the lateral movement observed along the Sand Hill and Honey Creek Faults reveals the fact that these movements are exactly opposite and therefore the faulting in Edmonson County and the neighboring district could not have been pro-

[2] C. K. Leith: "Structural Geology." Henry Holt and Co., New York, Revised Ed. 1923).

duced by east-west non-rotational compression, while the obtuse angles which are formed on the north and south sides of the intersections of the actual faults show that they were not produced by north-south non-rotational forces. The possibility of the formation of these faults by non-rotational stress can therefore be rejected.

In the case of rotational compression two main systems of faults are produced, but tension is also present and a third system of faults may therefore be formed.

Diagrams B and C show the two possible cases of compression by rotational stress which differ from each other only in the direction of the offset of the opposing forces. The orientation of the three fault systems is shown together with the lateral movement which would result and they are distinguished by the letters S, F and T indicating *shear*, *fracture* and *tensional faults*.

From each of the two cases, B and C, three different combinations may be obtained whereby two intersecting fault systems result. These three cases are: first *shear and fracture* faults, second *shear* and *tension* faults and third *fracture* and *tension* faults. Now by a comparison of the lateral movement along these theoretical fault systems with the observed movement along the Sand Hill and Honey Creek Faults certain cases may be rejected on account of their not corresponding with the conditions which were actually observed to exist in Edmonson County and the adjoining portion of Warren County. Three cases remain in which the lateral movement along one of the fault systems is similar to that which occurs along the Sand Hill and Honey Creek Faults. These cases are: first a combination of *shear* and *fracture* faults as in B, second a combination of *shear* and *fracture* faults as in C and third a combination of *shear* and *tensional* faults as in C. These three cases are illustrated by the diagrams D, E and F oriented and proportioned to conform to the faults as shown in figure 49.

Case F may be withdrawn from further consideration with safety. Tensional faults produced by rotational stress are of much less common occurrence than are fracture faults, and if this case were actually to apply to the district under consideration a suggestion at least of a system of faulting trending approximately north and south should be developed. No such faults or any indication of their presence have been observed in this part of Kentucky.

In cases D and E the results produced are identical and no field evidence would serve to indicate which of these might best be applied. A consideration of the regional structure, however, offers some suggestions and indicates the most probable solution of the problem. The adjacent Cincinnati Anticline as well as the folded Appalachian region farther to the east are oriented in a northeast-southwest direction and show an important crustel shortening in a direction normal to this which most probably was produced by compression in a northwest-southeast direction. Such compression corresponds to the hypothetical case D while case E is not in accord with this situation. The latter will therefore be removed from further consideration.

The rotational nature of the stresses required to produce faulting as in D is easily explained in view of the larger structural features of the Cincinnati Anticline. The uplift of the great dome which centers about Cincinnati at the northern end of the arch represents considerably more shortening than does the saddle which occurs just to the south and the twisting motion given by a thrust from the northwest to the region of the western flank, of which Edmonson County is a part, would result in an offset of the opposing forces as is shown in case D.

Age of Deformation.

No evidence is available to accurately date the time at which the deformation of Edmonson County took place. It is highly probable, however, that the faulting and folding of this region was a phase of the great movements which occurred at the close of the Paleozoic Era and which resulted in the folding of the Appalachian Mountains and the extensive warping along the axis of the Cincinnati Anticline. Minor movements along the faults may have taken place, however, as late as the early part of the last century as severe earthquake shocks were felt throughout this district in 1811.[3]

[3] N. S. Shaler: "Reports of Progress." Geol. Surv. Ky., N. S., Vol. 3 (1877), p. 237 (Pt. 3, p. 109).

CHAPTER X.

HISTORICAL GEOLOGY

Introductory Remarks.

From the study of geology the records of past events are discovered which are so far remote that human history is completely dwarfed by comparison. When these records are properly arranged in chronological sequence and interpreted, the various steps and stages in the historical development of the whole earth, of a continent or of a smaller area are made clear. The records, however, which are preserved in any particular area never are complete but some of the gaps may be filled in from the results of study in adjacent regions. Historically, no portion of the earth's surface has remained entirely isolated and every part has been influenced by certain world wide processes which may have produced different results in different places.

Similarly, every portion of a continent has been essentially related in its development to the development of the continent as a whole. In the consideration of the geologic history of a region advantage is taken therefore of all that is known concerning the evolution of the continent and this knowledge in turn has been derived from the piecing together of the fragmentary records which have been deciphered locally. The knowledge of the development of the entire continent is used so far as possible to explain the major events in the history of any given area and the detailed study of a local region rarely fails to reveal much new data, some of which may have an important bearing upon the developmental history of the continent itself.

The records of the events which have taken place throughout geologic time are preserved in two widely different manners. A region submerged beneath the sea accumulates a record of events in the sediments deposited. The kinds of material, the thickness and the structure of the sediments and the remains of organisms contained in them present to the geologist more or less definite information concerning the depth, salanity, and temperature of the sea, the distance from shore and the nature of the adjacent

land masses. On the other hand an area which rises above the sea is more or less subject to erosion. The configuration of the present land surface is the result of those processes which have been in operation throughout the time that the area has stood above the sea and in its topographic forms the various stages through which it has passed during the course of its more recent development may be discerned. The complete history of a region therefore must be interpreted from the study of both the stratigraphic and physiographic records.

As might be expected the older records are most obscured and frequently interrupted, but the events of the progressively more recent epochs commonly are preserved in a more and more complete sequence and the stages which shortly preceded the human era are recorded at many places in great detail.

Stratigraphic History.

General Remarks. It is known from the presence of the great series of sediments existing in the interior of North America that during Paleozoic time this region was occupied at intervals by rather shallow epicontinental sees which were connected successively or at the same time with the oceanic basins to the north, east, south and west. The outlines of these epicontinental seas were not constant but they advanced, withdrew and changed in shape many times during this era. The important land masses from which the sediments deposited in Kentucky were derived lay to the east along that belt which is now occupied by the Peidmont Plateau and to the north in Canada. Although sedimentation was certainly in progress throughout the area which is now included in western Kentucky during the Cambrian, Ordovician and Silurian Periods, the detailed character of the rocks formed is unknown as they are now completely buried beneath the younger formations. Ordovician and Silurian rocks are exposed, however, in the vicinity of Lexington and Nashville and consist almost exclusively of limestones, indicating widespread marine conditions far from shore. A history of the area included in Edmonson County cannot on account of lack of any specific records be projected back to any more remote time than the latter part of the Devonian Period while the actual details are not known preceding the St. Louis epoch.

Chattanooga Epoch. The deposition of the Chattanooga Shale marked a notable change in the Paleozoic conditions of sedimentation. The Middle Devonian sea in which calcium carbonate had been chiefly deposited withdrew probably in a northeasterly direction and the newly formed sediments were exposed to erosive action which was progressively more effective in a southerly direction. The deposits which had accumulated in Middle Devonian time were entirely removed in north central Tennessee[1] and considerably thinned in south central Kentucky.[2] The margin of the sea at this stage probably extended in a more or less east-west direction through the central portion of Kentucky, as the records preserved in the north central part of the state indicate that the sea was not withdrawn from this portion and that sedimentation continued uninterruptedly into the Chattanooga epoch.[3] This epoch was initiated by a wide expansion of the sea throughout the region which had so recently been land and the Chattanooga Shale was deposited unconformably upon Middle Devonion and Silurian beds.

The Chattanooga Shale was formed almost entirely from land derived sediment and its black color is due to carbonaceous matter probably of vegetable origin. These Shales were doubtless deposited in a shallow sea and their character suggests that they were derived from low-lying land clothed with abundant vegetation.

Unrecorded Interval. In western Kentucky the Chattanooga Shale is succeeded by the New Providence Shale, which is probably to be correlated with the Fern Glen Limestone in the Mississippi Valley region and is therefore the equivalent of the basal portion of the Osage Group of the Mississippian System. If the Chattanooga Shale is all Devonian there is a hiatus between it and the New Providence at least equal to the whole of Kinderhook time, but should the upper part of the Chattanooga be of Mississippian age as some investigators believe this interval is in part or perhaps wholly accounted for in the sedimentary record. Certain evidence, however, suggests that sedimentation did not take place during Kinderhook time. The Cincinnati

[1] Hayes and Ulrich: "Columbia Folio." U. S. G. S., Geol. Atlas No. 95 (1903).
[2] Shaw and Mather: "Oil Fields of Allen County, Kentucky." U. S. G. S. Bull. 688 (1919).
[3] Charles Butts: "Geology of Jefferson County, Kentucky." Ky. Geol. Surv., Ser. 4, Vol. 3, Pt. 2 (1914-1915), p. 193.

Arch was initiated and raised above the sea in late Silurian time; erosion had reduced this temporary land area to a peneplain by Mid-Devonian time and with a slight advance of the sea Middle and Upper Devonian beds were deposited completely across it.[4] In early Mississippian time a second uplift of the Cincinnati Arch probably took place so that the central part stood as a low island surrounded by shallow seas. This second uplift preceded the deposition of the New Providence and probably separated it from the Chattanooga epoch.

Early Osage Epoch. The New Providence Shale is composed of sediment which probably was derived largely from the erosion of the Cincinnati Island the thickening of this formation from 50 feet in Allen to 150 feet in Jefferson County being indicative that the sediments were derived from a northeasterly direction. That it was laid down in a shallow oscillating sea is shown by the crossbedding so characteristic of the formation and the numerous local unconformaties which are present within it. Although the New Providence is dominantly composed of clastic material marine life was locally abundant, and the calcareous skeletons of organisms, most conspicuous of which are the crinoids, make up the thin beds of limestone which occur throughout the formation. While the New Providence Shale was being deposited in the shallow portion of the sea bordering the Cincinnati Dome more purely calcareous sediment which makes up the Fern Glen and basal Burlington Limestones was collecting to the west and northwest in the deeper portions farther from the land.

Later Osage Epoch. New Providence Shale was succeeded in southern Kentucky by the cherty limestone referred to the Fort Payne Chert by Shaw and Mather. The Cincinnati Island however, was still contributing clastic sediments which formed the Kenwood Sandstone, Rosewood Shale and Holtsclaw Sandstone of Jefferson County. At the same time the upper Burlington and Keokuk Limestones were accumulating in the clearer waters of western Illinois, Iowa and Missouri, these different types of sediments being dependent upon the proximity of the

[4] A. McO. Miller: "The Geology of Kentucky." Ky. Geol. Surv., Ser. 5, Bull. 2 (1919), p. 77.

several regions to land areas capable of furnishing clastic materials.

Throughout the interior of North America the limestones of Osage age are characterized by numerous and conspicuous bands of chert, but the significance of the wide distribution of this material is not fully understood.

Warsaw Epoch. Sedimentation probably continued uninterruptedly from the late Osage to the Warsaw epoch. Conditions were somewhat similar but the limestones contain greater amount of clastic material in the form of shale beds.

Spergen Epoch. The Spergen Limestone was probably deposited conformably upon the Warsaw throughout western Kentucky. Where it is exposed in Jefferson County and farther north in Indiana it is composed of fairly pure limestone, indicating that clastic sediments had ceased to be contributed by land areas to the northeast and consequently the seas were clearer.

Erosional Interval. Throughout most of the Ohio and Mississippi Valley the St. Louis overlies the Spergen conformably, but about the margins of the Cincinnati Dome an unconformity separates these two formations. It is probable that the Spergen Epoch of sedimentation was followed by a slight uplift of the dome which brought the edges of the newly deposited limestone above the sea and rejuvenated the streams of this land mass which had been reduced to a state of peneplaination.

St. Louis Epoch. A slight advance of the sea took place at the beginning of the St. Louis epoch and a general slow subsidence of the interior of North America continued throughout the deposition of this formation. The lower part of the St. Louis contains considerable clastic material derived from the bordering land. This argillaceous limestone is in places more or less bituminous and it is not unlikely that this carbonaceous and oily material may have been produced by the decay of sea weeds or other marine plants which flourished at this time. The upper part of the formation is composed of dense chert bearing limestone containing only a very small amount of clastic material. At this time the St. Louis sea had reached its maximum extent and the distant shore line and the low relief of the adjacent land

combined to effect little transportation of clastic material into the sea which occupied western Kentucky.

Ste. Genevieve Epoch. The Ste. Genevieve epoch succeeded the St. Louis in western Kentucky without interruption of sedimentation. In southeastern Missouri these two formations are separated by a local unconformity indicating that the Ozark region was uplifted a little at this time, but the effects of this movement did not extend to the Ohio Valley. An extension of the sea, however, took place to the northeast as far as southwestern Pennsylvania. There was a general shallowing of the waters in the Ohio Valley perhaps due to the accumulating sediments which is plainly evinced in the oolitic texture and cross-bedded and ripple marked structures common in the Ste. Genevieve Limestone.

It is probable that during the Ste. Genevieve epoch the seas extended across the Cincinnati Arch for the first time since the latter part of the Devonian period.

Interval of Uplift and Erosion. At the close of the Ste. Genevieve epoch a general emergence occurred throughout the Ohio and upper Mississippi Valleys. The sea receded to the south and an extensive land area was exposed and subjected to erosion. Deformation was active locally in few restricted areas which at one place resulted in the removal of the entire thickness of the Ste. Genevieve,[5] but it is improbable that any movement took place along the Cincinnati Arch at this time. Although erosion prevailed throughout a wide region the effects which it produced are in many places obscured by reason of the similarity of the beds above and below the unconformity and because of the general presence of talus accumulations which hide the contact. It is probable, however, that at this time a general regional relief of some 100 feet was produced in western Kentucky.

Renault-Paint Creek Epoch. The epicontinental sea readvanced rapidly and the Chester sedimentation was inaugurated. In Edmonson County and its vicinity limestones were uniformly deposited and the Renault and Paint Creek formations grade into each other whereas to the west in Caldwell County and beyond they are separated by the Bethel Sandstone. Still farther to the west in Randolph County, Illinois, the Aux

[5] Stuart Weller: "Chester Series in Illinois," Jour. Geol., Vol. 28 (1920), p. 288.

Vases Sandstone is present between the Renault and Ste. Genevieve. It is not known certainly that the Aux Vases is actually older than any of the basal Chester limestone farther east and this formation may be the result of shore conditions grading in an easterly direction into shales and finally limestones such as are present in Edmonson County. The sand which constitutes the Aux Vases and Bethel was derived from lands to the north and west and probably was deposited mainly as deltas in a shallow sea modified somewhat by shore currents and wave action which served to transport some of the sand for considerable distances laterally. In Edmonson County, however, clear and rather shallow seas prevailed throughout Lower Chester time, situated at such a distance from the land that they were free from clastic sediments. Conditions closely duplicated those of the Ste. Genevieve sea and similar sediments, nearly pure limestones conspicuously oolitic and cross bedded in places were deposited.

Cypress Epoch. The Cypress epoch may have been separated from the Renault-Paint Creek by a short period of emergence. It was deposited in a shallow sea, but somewhat oscillating conditions seem to have prevailed during the latter part of the epoch. At one locality delicate fern leaves perfectly preserved in a fine shale indicating that terrestrial vegetation flourished in the immediate neighborhood, occur ten feet below a horizon containing large numbers of a few species of marine invertebrates recording the prevalence of marine conditions. A rather persistent thin coal seam near the top of the formation is evidence of the existence of a short interval of time during which the region stood slightly above sea level.

Golconda Epoch. No break has been recognized in Edmonson County between the Cypress and Golconda formations. The transition of sandstone through shale to limestone indicates an advancing sea which pushed the shore line far enough to the north so that only a small amount of clastic material in the form of fine clay was carried into this region to be deposited with the calcareous sediments. The less oolitic nature of the Golconda Limestone and the absence of cross bedding indicates that the sea may have been somewhat deeper than that which occupied this area during Lower Chester time and consequently that it may have been of greater extent.

Erosional Interval. The Golconda epoch was brought to a close by a retreat of the sea which left the Edmonson County region as land, and erosion began. It was but slightly effective and was active for only a short time.

Hardinsburg Epoch. The readvancing sea initiated the Hardinsburg epoch, and sand brought into the sea by the streams draining the land area to the north, perhaps from as far away as Canada, was spread out laterally and deposited. Conditions of sedimentation at this time were probably somewhat similar to those which prevailed during the deposition of the Cypress Sandstone. The absence of any land fossils, however, suggests that the shore line was somewhat more distant than during Cypress time.

Glen Dean Epoch. The Glen Dean epoch was initiated by an extensive readvance of the Middle Chester sea which again pushed the shore line far enough to the north to prevent the mingling of near shore sandy sediments with the accumulating limestone although some fine clay was introduced. The sea was similar in general to that which prevailed during Golconda time and limestone was again deposited. The shaly partings which separate the more massive beds of Glen Dean Limestone are suggestive of the recurrence at intervals of certain special conditions more favorable for the transportation of mud into this region. These shaly partings may have been occasioned either by short periods of unusually heavy precipitation in the land area to the north or by violent and prolonged storms which agitated the waters of the sea to a considerable depth and prevented the settling of the fine mud until it had been carried a great distance from the shore.

Leitchfield Epoch. After the culmination of Glen Dean time the sea again retreated and a change from conditions favorable for the accumulation of more or less pure limestone to conditions under which more clastic materials were deposited opened the Leitchfield epoch.

In the most westerly portion of Kentucky and in southern Illinois the sedimentary record shows that the Upper Chester sea shifted to the south and back again to the north four times and limestones and sandstones were alternately deposited. These oscillations must have been felt in the Edmonson County region,

but the effects produced were of a much less striking character than farther to the west. The sediments deposited here throughout Upper Chester time were chiefly shales with only minor amounts of limestone and sandstone. The difference in the contemporaneous sedimentation which took place in these two contrasted regions was perhaps the result of a slight uplift affecting the Appalachian land area at about this time. Such a movement may have been an early manifestation of the great mountain forming deformations which took place at the close of the Mississippian Period. The comparatively thick deposits of shale in sharp contrast with the underlying limestone beds seems to be indicative of crustal movement, while the gradation laterally into typical Chester limestones and sandstones to the west shows that the land area which was the source from which these sediments were derived lay at the east.

Epoch of Uplift and Erosion. The Mississippian Period was brought to a close by an extensive uplift of the eastern part of the North American continent which caused the sea that had so long occupied the interior to be withdrawn. The vertical uplift in the Edmonson County region was not great, but with the conversion of this area into land erosion commenced and drainage valleys were formed.

At this time an extensive mountain chain was formed in the old area of Appalachia, from which was produced by rapid weathering and disintegration the vast quantity of clastic sediments which were deposited during Pennsylvanian time.

Pennsylvanian Period. The Pennsylvanian sediments of western Kentucky are almost wholly clastic in character. In the early part of the period sand and gravel composed of rounded quartz pebbles were widely spread over the interior of the continent. The heavily laden currents which carried in this material carved channels over 200 feet deep in the Mississippian deposits which were later filled with the coarser materials brought down from the mountain areas to the east. After the violence of the early stages of this period had abated mud alternated with sand in building up the great thickness of Pennsylvanian sediments.

Throughout Pensylvanian time the region of western Kentucky stood very near sea level. It is not possible to determine

from much of the sedimentary record whether deposition took place in the sea or upon the land. The coal beds indicate the existence of stages of comparative quiet during which vast swamps luxuriant with vegetable growth covered considerable areas and little or no sediment was brought in. On the other hand, however, thin beds of limestone or shale bearing marine fossils are conclusive evidence that at times this region was submerged beneath the sea. Recurrent alternations between marine and terrestrial conditions of sedimentation must have taken place repeatedly, but it is probable that most of the Pennsylvanian strata was accumulated above sea level upon a vast alluvial plain which was at times flooded by marine waters.

Appalachian Revolution

Throughout Paleozoic time the interior of North America was occupied largely by intermittent epicontinental seas. It was alternately a submerged area in which accumulated various sorts of sediment, and emergent during which times no sediments were deposited, erosion on the other hand being more or less active. At the close of the Paleozoic era the eastern portion of the continent was uplifted, the Appalachian Valley was intensely folded into high mountains and from this time onward the eastern part of North America has never again been submerged but has been an area of repeated uplifts and continuous erosion. At this time the Cincinnati Arch was again bowed up, the extent of the folding being greater probably than that which had taken place in all previous time.

Physiographic History.

General Remarks. The history of the Edmonson County region as outlined in the foregoing pages has been deduced from the sedimentary record. The process of sedimentation preserves the details of the past, each succeeding formation which is deposited forming a protecting cover for the beds beneath it. Sedimentation ceased at the close of the Paleozoic and throughout the whole of the Mesozoic and Cenozoic Eras this region has been subjected to erosion. The history of this time cannot be deciphered from the sediments, for none were laid down here but must be reconstructed from the topographic configuration of the

country. The topography of a region is under most circumstances produced by erosion and the height and shape of the hills and the forms and courses of the valleys give some indication of the various stages in the erosional or physiographic history. In contrast with sedimentation which preserves the records of past happenings, erosion more or less completely destroys the evidence of what has gone before. Consequently although present conditions may be clearly seen the conditions which prevailed during the past are clouded in greater and greater obscurity. With the initiation of a new stage in the psysiographic development of a region the topography which has been produced during all preceding stages is at once attacked by erosional processes and eventually may be entirely obliterated.

Cretaceous Peneplain. The oldest extensive peneplain whose remnants have been preserved in the Appalachian region is believed to be of Cretaceous age. This peneplain was developed throughout the entire eastern part of the United States. The newly formed Appalachian Mountains were worn down and this whole region was reduced nearly to sea level. It is not unlikely that other peneplains were developed previously in earlier Mesozoic time, but no remnant of any of them remains to establish its former presence. Remnants of this Cretaceous peneplain in the form of more or less isolated knobs have been preserved in Edmonson County and the adjoining parts of Kentucky. It is probable that the course of Green River was already established at this time.

Late Cretaceous Uplift. In late Cretaceous time differential uplift occurred throughout the eastern United States and the extensive Cretaceous peneplain was elevated from its lowlying position some 300 feet in the Edmonson County region. This uplift may have taken place in several closely spaced intervals of time rather than as a single uniform movement.

Tertiary Erosion Cycle. An uplift of the extensive Cretaceous peneplain resulted in the rejuvenation of the streams and initiated the first cycle of erosion which is assigned to early Tertiary time. Many physiographic features of Edmonson County such as the hanging and abondoned valleys, high level flats and cave levels, suggests that the Tertiary erosion was

arrested temporarily at several levels and that the down cutting which was accomplished during this period should be assigned to several intervals of erosion, each of which apparently represented less time than any of the true cycles which preceded it. Late in the Tertiary, probably during the Pliocene, the region experienced slight uplift which had the effect of local terrace development.

Early Pleistocene Erosion Cycle. A small uplift again rejuvenated the streams which began at once to deepen their valleys. The main streams reduced themselves nearly to base-level, but this cycle was brought to a close before any flats worthy of the name were formed. Green River east of the mouth of Honey Creek as well as Nolin River and Bear Creek except for a few miles just above its mouth all are flowing now at essentially the same level to which they were cut during this early Pleistocene cycle of erosion, practically no downward erosion having been accomplished since that time.

Pleistocene Valley Filling. During late Pleistocene times the lower Ohio River carried much glacial water heavily loaded with sediment which rapidly aggraded or filled up its valley to a depth of about 100 feet. As Green River did not drain a glaciated district as did the streams to the north it was not supplied with enough sediment to keep pace with this aggrading process in the Ohio Valley and consequently the valley of Green River was dammed at its mouth and converted into a great lake. This lake gradually silted up through the deposition of material brought in by the back water from the Ohio and by the deposition of sediments contributed by Green River and its tributaries. This lake reached eastward as far as the mouth of Honey Creek in Edmonson County, and from this point westward its valley was filled up with sediment to a greater and greater depth.

Recent Valley Trenching. Since Pleistocene time the lower Ohio River has been gradually clearing its channel of the material deposited from the glacial waters. This process has resulted in the gradual lowering of the river level and the production of terraces. The effect of this slight depression of the base level has been felt but little as far up Green River as Edmonson County, and the dams and locks recently built across both this stream and the Ohio have brought this process to a temporary stop.

CHAPTER XI.

ECONOMIC GEOLOGY

General Remarks.

The potential value to industry of the mineral resources of Edmonson County is very great. As they lie undeveloped today, however, their actual value with the exception of the rock asphalt deposits is slight. This situation is due to the lack of means of transportation. The character of sediments with which the economically valuable materials are associated is responsible for the rugged topography in the county and its small value as an agricultural district, and these conditions are responsible for its being isolated, little known and seldom visited. The only mineral resource being utilized on a commercial scale at the present time is the rock asphalt which is being exploited by several companies.

The rock asphalt deposits of Edmonson county are almost unique in this portion of the United States. The absence of competition, the demand for the product, and the convenient situation of the deposits adjacent to Green River are the factors which account for the profitable expansion of this industry in a region where most other minerals could not possibly be produced successfully in competition with more conveniently situated deposits of similar type. Edmonson County is at present wholly without direct railroad transportation without which the full development of its mineral resources other than oil cannot take place. It is possible however that the product of the rock asphalt quarries may grow to be of sufficient importance in the near future to warrant the extension of railroad facilities into the county, and when such transportation is provided it is probable that other resources of the area will be utilized and that additional industries, chiefly of a ceramic nature, will spring up.

Rock Asphalt

Introduction. The rock asphalt of Western Kentucky is composed of rather coarse grained pure quartz sandstone thoroughly impregnated with bitumen of about the consistency of

warm tar. The proportion of bitumen present in the sandstone varies from a mere trace sufficient only to give the rock a grey color, to an amount sufficient to completely fill the interstices between the sand grains. The commercially important deposits consist of sandstone almost completely saturated with bitumen, but due largely to variation in the porosity of the rock the bitumen content varies from 3% or 4% to a maximum of about 15%, the average in the important rock asphalt beds being probably in the neighborhood of about 5%. Sandstone carrying 8% to 9% of bitumen is not uncommon and rock with as much as 12% is present in considerable quantities in many places. A bitumen content of 15% is revealed by certain analysis of fresh rock, but such occurrences are rather unusual and are of only local extent.

Rock asphalt deposits occur in Logan, Warren, Edmonson, Grayson, Hardin, Breckenridge and Hancock Counties. The deposits of Edmonson County are by far the most important and here the greatest amount of development has taken place. Three quarries are now in active operation and a fourth will be opened up in a few months, time. The total production of the county to date is about 1,500,000 tons, most of which has come from the quarries of the Kentucky Rock Asphalt Company.

The Kentucky rock asphalt finds its chief market as a material for surfacing streets and highways and has been employed for this purpose from Florida to Canada and from Vermont to Kansas. Some shipments have been made abroad. A smaller proportion is used for floors in factories, railroad shops and other industrial buildings. This material possesses certain important advantages over Trinidad asphalt, parteiularly in regard to the simplicity of laying and its failure to roll and buckle in hot weather under heavy traffic. The use of rock asphalt for surfacing pavements has passed the experimental stage and this product is now considered by engineers as one of the standard types of paving materials. This industry is firmly established in Edmonson County as a profitable commercial enterprise, and as the demand for rock asphalt now exceeds the supply and is steadily advancing, an attractive opportunity is offered for additional development.

Occurrence. In Edmonson County sandstones of both Chester and Pottsville age are impregnated with bitumen to an extent sufficient to be considered as rock asphalt. The Cypress as exposed in the beds of First, Second and Bylew Creeks is asphaltic locally as is also the Hardinsburg in the valley of Crooked Creek. These Chester horizons are, however, unimportant on account of their situations at low elevation and under extremely heavy overburden and they will be given no further consideration.

The rock asphalt of the Pottsville occurs chiefly at two different horizon, the first being in the upper part of the massive, basal or "conglomerate" sandstone and the second in the Bee Spring Sandstone. These two horizons are generally separated by a series of shaly beds in which occurs the Main Nolin Coal over that part of the county where it is developed. These two sandstones which carry the asphalt are rather unequally distributed throughout the Pennsylvanian portion of Edmonson County. The massive basal sandstone is developed to its greatest extent in the ancient channel from which it extends with more or less uniformity of character to the southern boundary of the Pennsylvanian area. North of the channel this basal member of the Pottsville is either absent or present as a thin discontinuous sandstone. The Bee Spring Sandstone, on the other hand, achieves its most characteristic development in the northern part of the county extending from the Hart County line to Sunfish Creek, but as it is traced southward it becomes more and more shaly and ceases to be a distinguishable member of the Pottsville section. These two sandstones separated by the horizon of the Main Nolin Coal are therefore more or less supplementary, occupying different areas which do not overlap to any great extent. At those localities where they are both present as massive beds the asphalt occurs in the lower and the generalization can be made that throughout the asphalt district of Edmonson County the important rock asphalt deposits occur in the first massive sandstone above the Mississippian. The massive basal sandstone of the Pottsville attains a maximum thickness of well over 200 feet, but asphaltic beds are with a few exceptions confined to the upper part, while the Bee Spring sandstone with a maximum development of about 50 feet may bear asphalt in any part.

The rock asphalt deposits of Edmonson County are largely confined to that portion which is bounded by Bear Creek on the west, Green River on the south and Nolin River on the east. It is known from the observation of outcrops and tests with the core drill that the proper horizon throughout most of this area is asphalt bearing. "Black rock" is reported to outcrop in practically every valley within these bounds except that area which lies to the southeast of the Honey Creek Fault. The exposures are, however, as a rule more continuous and richer south of Sycamore and Pigeon Creeks, this line coinciding in a general way with the northern extent of the massive basal sandstone member of the Pottsville. The difference in the number of exposures north and south of this line is probably the result of differences in stratigraphy rather than an indication of a less continuous asphalt bearing horizon to the north as in this part core drilling is said to have yielded very encouraging results. The massive basal sandstone possesses a marked tendency to stand in sheer and precipitous cliffs and bluffs while in many situations the Bee Spring Sandstone is covered by talus accumulations and consequently good exposures of the former together with its rock asphalt beds are of wider distribution than are those of the lattter.

Beds above the Bee Spring Sandstone are locally impregnated with bitumen to some extent, but they are either too thin, too lean or of too limited extent to be of any economic importance.

Apparently important deposits of rock asphalt occur over a limited area upon the west side of Bear Creek northwest of the quarry of the Kentucky Natural Rock Asphalt Company, while a few other less promising shows are to be seen on the west side of the creek between here and the Grayson County line. Rock asphalt outcrops to the south of Green River upon both sides of Little Beaverdam Creek, but core drilling has proved this to be of very limited extent. East of Nolin River core drilling is said to have revealed an important body of rock asphalt in the neighborhood of Ollie. Elsewhere, although outcrops are reported at numerous places, the extent of commercial deposits is almost unknown as this area has received less attention from the asphalt companies than any other. It is probable, however,

that a large tonnage of available rock asphalt is present in this direction.

The Rock Asphalt. Rock Asphalt of commercial grade may be seen at the present time in the various quarry faces as a single bed with a maximum thickness of about 30 feet. Diamond drill tests show that a thickness of 40 feet of high grade rock is not uncommon while a few cores indicate a sudden local thickening to nearly 100 feet. At most places the commercial rock is overlain by a greater or less thickness of lean sandstone stained dark grey with bitumen which is known locally as "black waste." It is not uncommon for the rock asphalt to be present as two or more beds separated by beds of barren or lean sandstone. Two beds separated in this way may be seen in the abandoned quarry of the Wadsworth Stone & Paving Company.

The rock asphalt beds although of wide extent are quite erratic as to local development. They pinch and swell, thicken and thin without apparent reason. At certain places, as for example the quarries of the Kentucky Rock Asphalt Company, there is an abrupt thickening of ten feet or more in a downward direction localized along a narrow zone which extends completely beneath the hill, being observed in both quarries and recognized in the diamond drill tests in the intermediate area, which resembles a small channel more than anything else.

The factors which control the localized presence of the bitumen in well defined beds are largely unknown. It seems probable that the texture of the sandstone would play an important part, but a careful comparison of the highly bituminous beds with the lean "black waste" above or below fails to reveal any textural differences more noticeable than those which occur within the richly asphaltic beds themselves. The upper and lower limits of the commercial rocks are, however, quite sharp and in many cases there is no transition whatever between 8% or richer rock and the "black waste," the separation occurring abruptly along an even line which in some cases may reveal no suggestion of bedding.

It is said that diamond drilling at closely spaced intervals show a rise of the rock asphalt under overburden in such a manner as to simulate to some extent the surface configuration of the land. It is also said to be generally true that the rock

asphalt is both thickest and richest adjacent to the outcrop and that both the quality and quantity decreases beneath heavy overburden.

FIG. 53. NATURAL ROCK ASPHALT.
Block of rock asphalt in the old Wadsworth quarry. Note the bleached surface of the sandstone as contrasted with the deep black of the fresh surface beneath the hammer. Above the hammer the bitumen has "bled" from the rock.

The sandstone which is completely impregnated with bitumen is composed of comparatively coarse, angular quartz grains. Small stringers and pockets of the characteristic quartz pebbles of the Pottsville rarely more than one half inch in diameter are locally present. Practically no cementing material other than the bitumen occurs and when this is burned out the sandstone crumbles into a white mass resembling glass sand.

The beds are either massive or crossbedded, the structure being made more apparent in some cases by local differences in bitumen content due probably to varying degrees of original cementation or difference in the grade sizes of the grain.

The freshly broken rock asphalt presents a dense black surface upon which the individual sand grains although apparent cannot be actually seen on account of the coating of bitumen which adheres to their surfaces. High grade rock feels sticky to the fingers and when struck with a hammer does not break into small pieces or disintegrate but mashes down into a flat compact mass. Prolonged exposure to the atmosphere, particularly the strong sunlight, has a tendency to bleach all but the richest portion of the rock asphalt. Some of the slightly bleached surfaces in more protected or damper situations are covered with a yellow dusting of sulphur produced no doubt by the oxidation of hydrogen sulphide. The richer portions of the rock on the other hand "bleed" during the hot summer months and small streams of bitumen run slowly down the side of the rock or tar-like drops hang suspended. Both the bleaching and bleeding of the rock asphalt may be well seen at the abandoned quarry of the Wadsworth Stone & Paving Company where numerous large blocks have lain untouched for six years. Natural outcrops of rock asphalt also exhibit these same phenomena and in addition at some places a case hardening or the formation of a limonite film over the surface has taken place. It is therefore the case at many localities that good rock asphalt shows upon the weathered surface no indication of its presence, this being apparent only upon fresh fractures.

The bitumen which impregnates the sandstone issues at certain localities in such appreciable quantities that they are known as "tar springs." One such occurrence is to be seen on the south side of the south fork of Hub Branch of Davis Creek. Here the bitumen is said to issue at the rate of nearly half a gallon a day in a small spring from which there is a continuous flow of cool, sweet water. The bitumen as it first issues from the rock is a pitchy black substance of the consistency of thick paint which rises to the surface of the water and spreads out into a floating mass one-eighth to one-sixteenth of an inch in thickness. At this time it possesses a viscous fluidity and clings tenaciously to any dry object which comes in contact with it. With exposure to the air the bitumen is either partially oxidized or loses some of its lighter constituents by evaporation. It becomes stiffer and finally sinks below the surface of the water. In this situation it remains unchanged but if removed from the water and exposed to the air it becomes stiff, heavier and less plastic and finally assumes the consistency of ordinary coal tar. The analysis of a sample of bitumen from Edmonson County is given below[1].

[1] D. D. Owen: "Report on the Geological Survey in Kentucky." (1856), p. 166.

Specific gravity	1.362
Moisture	0.0
Volatile combustible matter	59.7
Fixed carbon	14.3
Ash	26.0
Total	100.0

It is apparent from the specific gravity of this sample that it had been subjected to long exposure and it is probable that this was bitumen that had bled from the rock asphalt outcrop.

The bituminous material which forms the matrix of the rock asphalt occurs not only in sandstone but also in the cracks and bedding planes of the Main Nolin Coal at the Tar Lick Coal Bank and also in the pores of Chester limestone on the north side of Brier Creek three-quarters of a mile east of Nolin School.

Origin. The Bitumen of the rock asphalt deposits is clearly a substance which has been derived from petroleum. The whole rock asphalt district was at one time an enormous oil field and the asphaltic beds are in reality "fossil oil sands" from which the more volatile hydrocarbons have escaped as the result of the exposure of these beds at the surface by the downward erosion of the valleys.

No beds are known either in the Pottsville of this region or the underlying upper Mississippian formations which could have produced the vast amount of petroleum which the asphaltic horizons at one time contained. It is probable therefore that the oil migrated upward from much lower beds perhaps in situations similar to those of the producing "sands" of the Bowling Green district. That oil may migrate upward along joints in the limestone is known from observations six miles north of Bowling Green. Between the forks of the pike leading to Richardsville and Anna is located a county quarry from which road metal is obtained from the Renault-Paint Creek Limestone. In the course of work in this quarry in July, 1924, a small joint was encountered which was filled with light colored liquid petroleum. This horizon is about 1,000 feet above the Chattanooga shale from which the oil was probably originally derived.

The location of what are apparently the richest and most continuous rock asphalt deposits along the deeper part of the

old Pottsville filled channel in the north central part of Edmonson County suggests that the presence of this channel may have played an important part in the upward migration of petroleum in this vicinity. As has been shown oil is known to have migrated upward along joints and fractures in the massive compact limestone below the Cypress, but such migration would probably be brought to a stop by an impervious shale bed. The Chester Series with its alternating limestones and sandstones separated in most places by intervening shales and the shaly Leitchfield Formation at the top might be expected to present an impassible barrier to the rising oil. Erosion which preceded the deposition of the Pennsylvanian, however, carved a channel completely through the shaly beds of the Chester and any oil that might move upward through the underlying limestone would pass directly into the massive basal Pottsville sandstone. This sandstone is ideally adapted to form an oil reservoir and the petroleum finding its way into it would spread out laterally along those horizons which were texturally most suitable.

The migration of the oil into the Pottsville apparently did not take place until after the deformation which occurred at the close of the Paleozoic era. This is strongly suggested by the disposition of the rock asphalt deposits in the neighborhood of the Honey Creek Fault. Commercial deposits occur immediately upon the northwest or upthrow side of this fault while to the southeast the rock is either very lean or entirely barren. If migration had taken place before the deformation rich deposits would be likely to occur upon both sides of the fault and it is therefore probable that the joints up which the petroleum migrated were not opened up before the close of the Paleozoic.

At some time during the Tertiary Period erosion cut down to and exposed the oil bearing beds. A considerable part of the petroleum probably escaped and from that time until the present the remainder has gradually lost its more volatile constituents until now little more than the asphaltic base remains. The fact that the rock asphalt beds are in general thickest and richest adjacent to the outcrop shows that there has been a slow but continuous outward movement of the oil and the rising of these beds beneath the overburden indicates that a certain amount of rearrangement has taken place probably in accord-

ance with past and present levels of the ground water table while the presence of tar springs is evidence that movement of the viscous petroleum residue is still taking place.

History of Development. The rock asphalt deposits of western Kentucky have been known locally as "black rock" from the time of the earliest settlements and certain localities where the bitumen issued in small springs were formerly much frequented as a source of material for pitching boats engaged in the river traffic.

Rock asphalt has been recognized as an excellent paving material in Europe since the early part of the last century, and at the present time when a European engineer refers to an asphalt pavement without qualification he means rock asphalt. In 1872 European rock asphalt was laid in Union Square, New York City, and later in several other of our eastern cities, but the cost of importation almost prohibited the use of this material.

The first commercial interest to be taken in the Kentucky rock asphalt deposits was shown in 1887 when Charles Very, acting for William L. Breyfogle, of New Albany, started an examination of the eastern border of the Western Coal Basin which continued for five years. The results of this examination were so promising that considerable land lying chiefly in Grayson County was acquired, and in 1891 the American Bituminous Rock Company was organized to exploit these holdings and a plant was erected. Later a second plant was built near Grayson Springs to extract the bitumen from the asphaltic beds. About 80 barrels of this material are said to have been extracted, but the process was apparently not successful and the company soon ceased to operate.

In about 1899 the Federal Asphalt Company of Chicago took over the holding of the American Bituminous Rock Company. A plant was built near Big Clifty in Grayson County which shortly afterward burned down. The company went into bankruptcy and the property was sold for taxes.

In 1904 the Wadsworth Stone and Paving Company, of Pittsburgh, was organized and opened a quarry in Edmonson County on the north side of Green River one mile northeast of Davis Ferry. It was originally intended that the product of this company should compete with imported Sicilian asphalt used

chiefly for brewery floors. This company prepared two different types of products, ordinary finely crushed rock asphalt and a mastic composed of 75% pulverized limestone, 20% rock asphalt and 5% of liquid bitumen.

About this time experimentation in the construction of rock asphalt roads was undertaken in earnest and in 1904 this material was laid cold for the first time. The public square in Bowling Green was paved in 1905. In 1906 the Government laid a few hundred yards on the Cemetery Pike just outside of Bowling Green. Between this time and 1910 rock asphalt had been employed in the construction of roads in Indiana, Michigan, Ohio, Pennsylvania, New York and Virginia as well as various parts of Kentucky.

In 1907 a Mr. Hatch opened a quarry on the north side of Indian Creek which was worked for about 18 months, the rock asphalt being hauled by wagon to Nolin River and thence shipped in barges to the Barber Asphalt Company in St. Louis. It is said locally that the Barber Asphalt Company, then the foremost company dealing in Trinidad asphalt, purposely laid the Kentucky product improperly in order to discourage its use and prevent the introduction of a competitive material.

About 1906 Judge M. M. Logan began the acquisition of asphalt properties in Edmonson County which he continued until 1917 when the Bee Spring Land & Mining Company was organized. The holdings of this company totaled about 40,000 acres. Stock was issued to land owners in exchange for their mineral rights at the rate of five dollars per acre.

The Wadsworth Stone & Paving Company continued in operation from 1904 until 1917 with an average annual production of about 10,000 tons, when it with the acquisition of additional capital was combined with the Bee Spring Land & Mining Company to form the present Kentucky Rock Asphalt Company, of Louisville. In this combination three-quarters of a share of stock in the new company was exchanged for each share in either of the former. The Kentucky Rock Asphalt Company continued operation at the old Wadsworth quarry for one year, then moved to its present location at Kyrock on Nolin River.

In 1922 the Kentucky Natural Rock Asphalt Company was organized and has since been operating north of Gulf Hollow on Bear Creek.

In 1922 Overall and Owen former oil operators in Allen County, became interested in the rock asphalt deposits and in the course of three years' time have acquired approximately 18,000 acres of land in the southern part of the Edmonson County asphalt district. Recently they have turned over a portion of their holdings to the newly formed Rock Asphalt Company of America with offices in Louisville. The properties of this company have been recently purchased and merged with other operating units of the United Rock Asphalt Company.

At the time that interest first became active in the Edmonson County rock asphalt deposits a large part of the land was owned by residents of other parts of the country interested largely in the native timber of the region. At the present time the mineral rights of all of the land and also the surface of a considerable portion are owned by persons interested in the rock asphalt. The two largest holdings belong to the Kentucky Rock Asphalt Company and Owen & Overall. The former controls 40,000 acres. Of this 15,000 acres are located on the east side of Nolin River, largely in the neighborhood of Ollie, the remaining 25,000 acres includes most of the land between Bear Creek and Nolin River north and east of Beaverdam Creek and the Brownsville Road. The 18,000 acres of Owen & Overall, of which 3,000 have been turned over to the Rock Asphalt Company of America, includes most of the country between Bear Creek and Nolin River and north of Green River south of the holdings of the Kentucky Rock Asphalt Company. The remainder of the land is distributed about as follows: Morrison Estate of Cleveland, 7,000 acres; Ayer & Lord Tie Company of Chicago, 7,000 acres, of which 2,000 acres lie within Edmonson, the remainder being included in Grayson County; Premier Asphalt Company of Cleveland, 2,300 acres; Judge M. M. Logan, of Bowling Green, 1,600 acres; Crump Asphalt Company, 1,000 acres on the north side of Dismal Creek; Arnold Heirs, 700 acres near Sweden: Standard Asphalt Company, 650 acres along Brier Creek; Natural Rock Asphalt Company, 600 acres along Gulf Hollow. Smaller tracts are held by Miss Hobson of Bowling Green and J. C. Van Meter of Bee Spring.

Many of the original land owners parted with their mineral rights for sums as small as thirty cents per acre. Five dollars was considered as a good price, but a large part of the mineral rights found their way into the hands of the companies and speculators at an average of about one dollar and a half per acre. Some of the mineral land thus acquired has been prospected and turned back as uncommercial.

Kentucky Rock Asphalt Company. The Kentucky Rock Asphalt Company of Louisville was organized in 1917 and operated for one year at the quarry of the old Wadsworth Stone & Paving Company, after which it moved to its present location at Kyrock. Two quarries are now in operation, one on either side of the hill which rises between the mouth of Pigeon and Pine Creeks. The daily production at the present time is close to 1,000 tons. The approximate production by years from the time of the organization of the company is as follows:[2]

1918	60,000
1919	70,000
1920	130,000
1921	140,000
1922	100,000
1923	150,000
1924	180,000
1925 (first half)	100,000

The quarries are located at an elevation of about 235 feet above Nolin River. Rock from five separate faces in the quarries is delivered simultaneously to the crushing mill which is located just beneath the north quarry. It is here passed through a jaw breaker and then goes by conveyor to the pulverizing mill situated just above Pigeon Creek. From the mill it is loaded directly in barges, which are then towed to Bowling Green, a distance of 71 miles. Throughout the process of milling samples are frequently and systematically taken and analysed to insure uniformity in the resulting product. The bitumen content of the material as shipped varies between 6½% and 8%.

[2] These and the following figures are based on the authority of Judge M. M. Logan, of Bowling Green.

During 1924 the average price of the product sold by this company was $8.23 per ton, F. O. B. Bowling Green, while the cost of production is estimated at about $5.00. The profits for this year represented a return of 23% on invested capital and an 8% dividend was declared to the stockholders.

FIG. 54. A ROCK ASPHALT OPERATION.
View of the quarry of the Kentucky Natural Rock Asphalt Company. The men with the power drill are standing upon the boundary between the rock asphalt and the overburden.

Kentucky Natural Rock Asphalt Company. The Kentucky Natural Rock Asphalt Company organized in 1922 opened a quarry on the north side of Gulf Hollow. A contract was made with an experienced quarryman to deliver 50,000 tons on barges in Bear Creek during 1923 at a price of $1.25 per ton. The contractor spent about six months in getting started and then coming to the realization that the rock could not be produced at the price broke his contract and left. The company then took over the operation of the quarry, but the year was practically lost to them. In 1924, however, about 25,000 tons were produced and the daily production at the present time is something under 300 tons.

The rock is crushed at the quarry and loaded on barges eight miles above the mouth of Bear Creek, which is very narrow and difficult to navigate. These are towed down Green River

to Rock Port, a distance of about 80 miles, where the pulverizing mill is located.

United Rock Asphalt Company. The Rock Asphalt Company of America was organized in Louisville in 1924 to exploit a portion of the property held by Owen & Overall. Recently this organization was purchased by the United Rock Asphalt Company, the present operators. The quarry has been opened about one and one-half miles north of Green River on the West side of Honey Creek. A narrow-gauge railroad has been built from the quarry site to the mill which was constructed on Green River. The mill consists of jaw breaker and pulverizer and the fully prepared rock asphalt is barged to Evansville for shipment. It is expected that production will start in a few months time.

Quarrying and Preparation. Although the rock asphalt workings of Edmonson County are known locally as "mines" they are open pit quarries. Mining was at one time attempted at the old Wadsworth quarry but the asphalt-soaked sandstone is so tough that it is practically impossible to produce it in this way.

The overburden is removed some distance in advance of the quarrying operations. Power drills are used and the blasting is done with dynamite. Overburden, waste and commercial rock are all handled by steam shovel and the last loaded in dump cars for transport to the mill. Experienced men capable of judging the quality of the rock supervise the loading. At the quarry of the Kentucky Rock Asphalt Company about four tons of overburden and waste are moved to each ton of commercial rock. Local labor is used exclusively and wages range from $2.50 per ten hour day and up.

The preparation of rock asphalt for the market is a simple process, consisting first of crushing the blocks as received from the quarry and then passing between rolls which, so far as is possible, reduces the rock to individual sand grains.

Specifications. Kentucky rock asphalt used in the construction of the early pavements was not carefully selected in accordance with the amount of bitumen present. After a number of years, however, samples were taken from those roads which had stood up best under traffic. These were analyzed and it was decided that a 7% content of bitumen was best adapted for

paving purposes. At the present time therefore careful grading takes place in both quarries and mills and the final product varies between 6½% and 8% bitumen to comply with the usual specifications.

The opinion has been expressed by certain engineers that 5% rock asphalt is equally well adapted for street and road construction as is 7% rock. As an experiment 5%, 6%, 6½% and 7% rock asphalt was laid some years ago on the Boat Landing Pike north of Bowling Green. At the present time no difference can be seen between the various parts of this pavement and one who did not know overwise would never suspect but that the material employed was of uniform grade. A reduction in the specifications regarding bitumen content from 7% to 6% would make available for almost immediate use many thousands of tons of rock asphalt which on account of the past and present standard have been discarded at the quarries.

Construction and Maintenance. Pavement construction with Kentucky rock asphalt is a comparatively simple process requiring less labor than any other standard type. The road is graded and the foundation of crushed limestone laid and rolled the same as is done in other types of paving. The crushed rock asphalt is then spread over the foundation, raked to a uniform thickness and rolled. One ton of rock asphalt will serve to surface from 15 to 25 square yards of pavement, depending upon local conditions and requirements. No treatment of the rock asphalt is required. It is used just as received from the mill and is rolled cold. The surfacing must be done when the foundation is dry and the temperature is above 60 degrees F., although warmer weather is better. It is possible that a steam heated roller could be used satisfactorly in surfacing pavements when the temperature falls below sixty degrees.

Any failure in a road properly surfaced with Kentucky rock asphalt is due to imperfections in the foundation. These can be repaired in the ordinary way by locally strengthening the foundation and resurfacing. The surface itself never wears out and the old surface may be taken up and relaid over the patches.

Kentucky rock asphalt is also extremely well adapted for repairing and resurfacing worn out pavements of other types

particularly macadam and brick. In the case of an old macadam road the surface must be brushed well to remove all dust, the chuck holes and ruts filled with crushed limestone and rolled and the whole surface roughened by means of a spiked steam roller. The rock asphalt is then applied evenly and rolled. Brick pavements can be repaired very cheaply and well with rock asphalt on account of the ease with which patches of the material can be feathered out.

Conclusion. Natural rock asphalt deposits are extensively distributed about the eastern border of the Western Kentucky Coal Basin in both the Chester and Pottsville sandstones. Some of the best and most extensive are located in the Pottsville of north central Edmonson County. Within the last 20 years an important industry has grown up here which will undoubtedly be greatly enlarged in the near future. Adequate railroad transportation would do more than anything else to hasten the development of this district.

Kentucky rock asphalt is now recognized as an excellent material for surfacing streets and highways and examples of this type of pavement may be seen in more than 25 states. These pavements are dustless, noiseless and practically traffic proof and when wet they are less likely to cause skidding than some other types. Rock asphalt possesses certain advantages over other paving materials particularly with regard to simplicity of construction, saving in labor and ease of repair. The cost of this type of pavement is ordinarily less than the hot mix sheet asphalt and in many cases less than inferior types. Crushed rock asphalt may be kept in storage for indefinite periods for use at a moment's notice without deterioration, and it requires no preparation before it is used.

The tonnage of rock asphalt available in western Kentucky and Edmonson County in particular is enormous. The proven quality of the roads constructed with it and its recognition as one of the highest types of paving materials, together with certain advantages which is offers, justify the expectation that this material will steadily grow in popularity and a mineral industry of the first magnitude will grow up in this district.

Petroleum

Production. The petroleum production in Edmonson County is small and comes from a few wells restricted to a small area near the southern boundary of the county west of Rocky Hill. No figures are availble to show the actual production from these wells.

Drilling. Drilling for oil in Edmonson County dates back to that period of excitement which spread over the whole of Kentucky shortly after the Civil War. Four or five wells were sunk at that time near Dismal and Brier Creeks and Davis Ferry. The deepest of these was probably in the neighborhood of 800 feet and in none of them was the upper oil "sand" of the Bowling Green field reached. Later prospecting in the county followed the discovery of the Bowling Green field in 1914 and in the succeeding six years five wells were drilled in addition to those of the small producing area west of Rocky Hill. This drilling was largely centered around Rhoda. The deep well the record of which has been given in detail on page 80 is located a short distance southwest of Rhoda, a second one 900 feet in depth is just north of this hamlet and a third of about equal depth is one and one-half miles to the northwest.

Still another well located one-half mile south of Silent Grove School was drilled to a depth of 1402 feet. The hole most recently drilled is located near the cross roads two and one-quarter miles due north of Turnhole Ferry. Shows of oil are reported to have been obtained in each of these wells but the horizons at which the oil occurred are not known except in the case of the deep well southwest of Rhoda. Locally, the show in the Silent Grove well is said to have been extremely good and it is reported that oil is standing in the well today from which the neighbors occasionally bail out small quantities. In the J. W. Cook well southwest of Rhoda only one show of oil was encountered, this being in the limestone about 100 feet above the black shale.

Influence of Structure on Accumulation. No data in regard to the influence of structure upon the accumulation of oil is to be had from Edmonson County. In Allen County, the conclusions of Shaw and Mather are that although the evidence is somewhat contradictory since the production is obtained at

some places upon anticlines while elsewhere producing wells are located in the synclines and the anticlines are dry, the structural features doubtless exert an important influence upon the location of the oil reservoirs, but they certainly do not absolutely control their positions, the composition and porosity of the oil "sand" being the most important controlling factor in some cases. In the Bowling Green field somewhat similar conditions obtain and from the distribution of the wells in this field the operators have concluded that, other conditions being favorable, the best production is to be obtained upon the northwest slopes of the structures. Examination of structural contour maps of portions of this field also shows that closure of the structures is by no means necessary, several of the best pools being located upon terraces which only interrupt the gentle northwest dip general to the whole region.

Oil "Sands." The oil bearing horizons or oil "sands" in the producing fields adjacent to Edmonson County are porous and in places more or less sandy limestones and dolomites. Nowhere in this region is the producing bed a true sandstone. The well records which are included in Chapter V show the absence of any true sand horizon above that which has been correlated with the St. Peter occurring at depths of 1735 to 1930 feet below the black shale in the J. W. Cook No. 1 and the Lena Doyle No. 3 wells. However "sands" are recorded in many of the logs, but this term has been applied by the drillers to any bed which is similar in texture of those from which the oil is produced. These "sands" are without exception limestones or dolomites and they owe their value as oil reservoirs to a porous texture probably developed either by solution or by recrystallization.

The important producing area nearest to Edmonson County is the northern extension of the Bowling Green field which lies upon the north side of Barren River. A number of wells have been brought in in this district which flowed over the casing head, the maximum initial production from a single "sand" being about 250 barrels. There are here two producing horizons known locally as the shallow and the deep "sands." The shallow "sand" is recognized in nearly all of the wells although it is by no means a consistent producer, and in more than half of the wells which produce from the deep "sand" it contains little

more than a show. In a few wells, however, good production has been obtained from this upper horizon. The shallow "sand" varies between 5 and 25 feet in thickness although 10 feet is its usual development. It occurs from 302 to 351 feet above the black shale and its location is believed to be in the lower part of the St. Louis Limestone.

Most all of the oil produced in Warren County north of the Barren River comes from the deep "sand." This horizon is far more consistent as an oil bearer than the shallow "sand," but the amount of oil produced varies widely between adjoining wells. This "sand" ranges in thickness from 12 to 35 feet with a usual development of about 15 feet. It lies from 80 to 107 feet below the black shale probably in the upper part of the Silurian Limestone. Stray shows of oil and gas are reported at depths of 48, 59, 348 and 1247 feet beneath the black shale.

The above discussion of the northern extension of the Bowling Green field shows clearly that the horizon at which oil might most probably be expected in Edmonson County lies in the neighborhood of 100 feet below the black shale. With the exception of the J. W. Cook well and the producing wells near Rocky Hill none of the test holes that have been drilled in the county have been carried to a sufficient depth to reach the position of the deep "sand" of northern Warren County. The J. W. Cook well, although of more than sufficient depth for a good test, records not even a show of oil at this horizon. The wells at Anneta and Meredith in Grayson County encountered shows at 107, 164 and 193 feet below the black shale but no production was obtained. These three wells all show the absence of an oil producing horizon below the black shale, but none of the other tests within Edmonson County are of sufficient depth to give any evidence concerning the presence or absence of this horizon. Shows of oil encountered in these tests as well as those recorded at 658, 438, 86 and 17 feet above the black shale in the J. W. Cook well and the wells at Anneta and Meredith are all believed to be of the nature of stray "sands" and the indications for a producing horizon above the black shale are not promising.

The asphalt impregnated sandstones which occur so abundantly upon the north side of Green River are in reality fossil

oil sands. At one time before the erosion of the overlying sediments these asphaltic sandstones were saturated with petroleum, but as the land surface was worn down by erosion a large part of the oil seeped out and escaped while the remainder lost its volatile constituents and now the asphaltic base alone remains. The oil which was formerly held in these sandstones must have migrated upwards from lower horizons, as there are no known beds in either the upper Mississippian or the lower Pensylvanian from which the oil could have been originally derived. This oil as a result of migration upward from lower horizons must have reduced the oil content of the deeper beds and it is probable that in those areas where the asphaltic sandstones are best developed the oil has been completely drained from the underlying horizons and consequently no production may be obtained by drilling.

In the extreme northwestern portion of Edmonson County it is possible that upward migration similar to that which has produced the asphaltic sandstones took place, but as the sands into which the oil may have moved have not been uncovered by erosion it may still remain and in this district production might be obtained from sands either in the Chester or lower Pennsylvanian strata. If this condition prevails the structure would undoubtedly play a more important role in the concentration of the oil than it has done in the lower Mississippian and underlying horizons because of the more consistently porous texture of true sandstone.

Recommendations for Prospecting. The structural contours which are over printed on the geological map of Edmonson County cannot on account of their generalization and lack of details as explained in Chapter IX be used as an absolute guide for prospecting. The construction of an accurate structural map would be a difficult undertaking requiring a detailed instrumental survey. Any closures which actually occur within the county are without doubt of small extent and such structures would not necessarily be present also in the underlying beds where the occurrence of an oil bearing horizon might be expected. The contoured horizon is separated from the position corresponding to the deep "sand" of northern Warren County by two unconformities as well as a considerable thickness of variable beds. For this reason and also because of the fact that the accumula-

tion of oil in the porous limestone is not altogether controlled by structure it is doubtful whether such a survey would be of great material aid in the selection of locations for test wells.

A careful consideration of the geological conditions which are prevalent in Edmonson County suggests certain points which should be noted in connection with oil prospecting within this area. These are:

1. Structural features of the beds exposed at the surface may give little indication of the position of oil pools at depth.
2. Those areas in which sandstone beds are heavily impregnated with asphalt are unpromising as these deposits are indications that a large part if not all of the oil has migrated upward and escaped.
3. There is little possibility of the occurrence of an oil producing horizon above the black shale in the vicinity of Rhoda as shown by the test wells which have been drilled near there.
4. Only one of the test wells drilled within the county penetrated to a sufficient depth to test the horizon beneath the black shale.
5. Any test well which may be drilled in the future should be continued to a sufficient depth to penetrate the horizon 100 feet below the black shale.
6. In the northwestern part of the county structure may possess a more important influence upon the location of oil reservoirs than it does elsewhere, providing that upward migration similar to that which produced the asphalt deposits has taken place.

The above discussion is by no means intended to discourage oil prospecting within Edmonson County. The facts and conclusions presented above simply indicate that geological information derived from the outcropping formations is of less aid here than elsewhere in directing intelligent exploration. The oil shows encountered in all of the more recent tests and the extensive asphalt deposits indicate conclusively that Edmonson County lies within the productive oil belt and the occurrence of good oil pools within this area seems entirely possible. The discovery of any such pools will depend to a large extent upon chance and a rich strike may be the reward of some prospector with sufficient capital and courage to insure himself against disappointment should his first attempts prove to be unproductive.

Coal

General Remarks. Five coals are present in Edmonson County; one in the Chester and the remaining four at various horizons in the Pottsville. They come to the surface extensively throughout most of the Pennsylvanian area and have been opened on a small scale at many places. The small local demand has been satisfied from strip pits and no underground workings have ever been opened except at one locality on Dismal Creek where an entry is said to have been driven back under the hill for a considerable distance. Work in the strip pits is confined entirely to the fall and early winter months and at the time when this district was examined almost all of its pits had caved in or were filled with water and the coal was actually observed at only a few localities and here exposures were so poor that good sections could not be obtained. Practically all information regarding the nature and thickness of the coal therefore was received second hand. Such information is not reliable as there is a natural tendency for exaggeration, particularly with regard to the thickness.

The current price of coal at various Edmonson County pits ranges from 15 to 20 cents per bushel.

Chester Coal. A rather persistent coal is reported to occur in the shales at the base of the Golconda limestone in Grayson, Hart, Edmonson and Warren counties. Its thickness at most localities is about three inches and it is of no economic importance although in past years it has been used for smithing at a few places.

Main Nolin Coal. The Main Nolin Coal which occurs at a horizon in the lower part of the shale zone below the Bee Spring Sandstone is the most important coal of Edmonson County both on account of its thickness and its occurrence at or near the surface over a rather wide area. The thickness of this seam averages about three feet although 42 inches are reported at several localities. It has been dug most extensively along Dismal Creek at the Tar Lick and Knob Lick coal banks. At the former locality one and one-half miles east-northeast of Bee Spring the coal is saturated with bitumen and stands in high favor locally on account of the ease with which it is kindled. This coal has also

been stripped on Nells Branch, Mill Branch, Sycamore Creek, Beaverdam Creek, Gulf Hollow and in the neighborhod of Segal. It also occurs south of Green River upon both sides of Little Beaverdam Creek and west of Bear Creek below Huff, in Laurel Branch and east of South Union Church. The coal east of Nolin River on Longfall and Brier Creeks and near Ollie is probably the eastern extension of this same seam. In the region east of Segal and south of Sweden the Main Nolin Coal, however, is apparently absent.

The following analyses show the character of this coal north of Bee Spring.[3]

	1	2	3
Specific gravity	1.282	1.350	1.345
Hygroscopic moisture	2.30	3.60	2.60
Volatile combustible matter	32.10	33.00	33.80
Coke	65.60	63.40	63.60
Total	100.00	100.00	100.00
Total volatile matter	35.40	36.60	36.40
Fixed carbon in coke	56.30	54.40	53.14
Ash	9.30	9.00	10.46
Total	100.00	100.00	100.00
Character of coke	Cellular	Spongy	Spongy
Color of ash	Light lilac gray	Lilac gray	Light gray
Percentage sulphur	1.059	2.101	2.425

No. 1 is from Tar Lick; No. 2 from Mill Branch, and No. 3 from Knob Lick.

The following is an analysis of the Main Nolin Coal furnished by the Kentucky Rock Asphalt Company. The sample was taken from an outcrop on the Basham tract adjacent to Bear Creek and shows that the coal here is of much better quality.

	As received.	Dry basis.
Moisture	4.09	0.0
Volatile combustible matter	39.33	41.01
Fixed carbon	51.62	54.85
Ash	3.97	4.14
Sulphur	2.08	2.17
B T. U.	13470	14045

[3] Robert Peter: "Chemical Report." Geol. Surv. Ky. N. S., Vol. 1, Pt. 4 (1876), p. 67.

The following analyses were made from samples taken near Segal.[4]

	1	2
Moisture	4.23	4.30
Volatile matter	35.07	31.70
Fixed carbon	42.42	36.85
Ash (red)	18.28	27.15
Total	100.00	100.00
Sulphur	4.37	9.45
Coke	60.70	64.00
Character of Coke	Cellular	Very dense

The above analyses show a great deal of variation in the quality of the Main Nolin Coal at different localities.

Second Pottsville Coal. The second Pottsville coal occurs a short distance above the Bee Spring Sandstone. It is thin and probably discontinuous and has been opened up at only a few localities. One small pit is situated below the Upper Morgantown Road one mile northwest of Steep Hollow School. One-half miles west of Grassland this coal outcrops in the stream bed, showing a thickness of about one foot with the bottom not exposed. The neighbors are contemplating opening a coal bank here in the near future. One-half mile south of Big Reedy a coal about 14 inches thick has been stripped on a small scale. This is probably a western extension of the second Pottsville coal seam.

Third Pottsville Coal. Next to the Main Nolin Coal the third Pottsville coal is the most important within Edmonson County. It maintains itself quite persistently throughout the hills in the northwest corner of the county beyond Sunfish and Bear Creeks. This coal has been opened at a number of localities and is said to run about two feet thick, although greater thicknesses are reported locally. No analyses of this coal are available.

Fourth Pottsville Coal. The Fourth Pottsville coal is thin and of only local occurrence a short distance above the third seam. It is not worked and is of no importance.

[4] J. O. Bryant: "Economic Geology of a Portion of Edmonson and Grayson Counties." Geol. Surv. Ky., Ser. 4, Vol. 2, Pt. 1 (1914), pp. 180 and 181.

Conclusions. The coals of Edmonson county are in general thin and of rather low quality and there is little prospect of their ever being of much economic importance. Their wide distribution throughout the Pennsylvanian area, however, and the many situations where they may be obtained by stripping adapts them excellently for satisfying local demands for this type of fuel.

Limestone

Building Stone. Nearly 100 years ago the first stone quarries located in the Renault-Paint Creek Limestone were opened near Bowling Green and have been worked continuously ever since. At the present time the Bowling Green "White Oolite," as it is known commercially, has become famous. Its market lies mainly within the states of Kentucky and Tennessee although it has been used in buildings in New York City, Gulfport, Miss., Miami, Fla., Washington, D. C., Philadelphia, Pa., Chicago, Ill., and many other cities. The same stone which maintains an important industry at Bowling Green outcrops upon the southern slope of the Dripping Spring Escarpment and upon the sides of the valley sinks of Edmonson County.

This stone occurs in two or more layers from 10 to 20 feet in thickness and is composed almost entirely of oolitic grains ranging in size from one-thirtieth to one-fiftieth of an inch in diameter. In composition it is remarkably pure calcium carbonate and contains on an average only about 2% of impurities. Major J. M. Reilly, of the Ordnance Department, U. S. A., reports a crushing strength of 6,532, 7,009 and 6,746 pounds per square inch for three samples which were tested by him. The stone as quarried in the vicinity of Bowling Green is generally stained with petroleum, but upon exposure these stains bleach out entirely and the stone soon acquires a uniform nearly pure white color. It stands the ravages of weather excellently, the carving upon the columns of the Bowling Green Court House being still as fresh as they were the day the building was erected 50 years ago.

In Edmonson County this white oolitic limestone generally occurs beneath heavy overburden and consequently is not favorably situated for quarrying. It is possible, however, that a careful search among the hills north of the Dixie Highway adjacent to the east line of the county might lead to the discovery of locations where quarries could be operated economically.

Lime. At the present time the demand for high calcium lime for chemical purposes is increasing rapidly. It is used in the manufacture of alkalies, sugar, glass, paper and many other commodities. The purity of such chemical lime is of primary importance and at the present time the highest grade produced in the middle west comes from the Spergen Limestone near Ste. Genevieve, Missouri. The limestone which is burned at this locality is a pure white oolite simlar to the white oolitic beds of the Renault-Paint Creek in Edmonson County and adjoining parts of Kentucky.

An analysis of a sample of this oolitic limestone taken near Glasgow Junction is given below.[5] This sample was taken at random. It is probable that this oolitic limestone when burned would produce a lime that might compete actively with the Ste. Genevieve product. It is to be noted in this connection that the purity of the Ste. Genevieve lime is only one of the features which makes it of exceptional value, the other being its oolitic structure, which is to some extent preserved in the lime. The oolitic beds in the Renault-Paint Creek Limestone of Edmonson County possess both the purity and texture of the Ste. Genevieve deposit and should produce lime of equal grade.

Aid dried at 212°	
Specific gravity	2.678
Lime carbonate	98.050
Magnesia carbonate	.363
Alumina, iron and manganese oxides	.511
Phosphoric acid	.051
Sulphuric acid	.260
Potash	.115
Soda	327
Silica and insoluble silicates	1.060
Total	100.737

At those localities where the oolitic limestone can be quarried greater returns could probably be obtained from the pro-

[5] Robert Peter: "Chemical Report." Geol. Surv. Ky. N. S. Vol 1, Pt. 4 (1876), p. 153 (17).

duction of building stone rather than lime, but where the overburden is too heavy to permit quarrying it would be possible to mine the rock for burning by means of tunnels and underground workings as is being done at the present time at Ste. Genevieve.

Road Metal. The Mississippian limestones which outcrop abundantly throughout Edmonson County with the exception of the northwestern portion are excellently adapted for some kinds of road construction. These beds are for the most part hard, compact and tough, and the old cobbles to be seen on some parts of the Dixie Highway bear good evidence of their durability under hard and long continued traffic. This limestone when crushed to a proper size forms a valuable road building material and the presence of an abundant supply convenient to the needs of the greater part of the county should exert a stimulating influence upon the good roads movement in this part of Kentucky. However, advantage has not been taken of the abundant limestone and with the exception of the Dixie Highway the roads that have been metalled are badly in need of repairs.

Cave Onyx

The term *onyx* is properly applied to a banded variety of chalcedony which closely resembles agate. The travertine deposits of caves, however, have been called "onyx" or "Cave Onyx" for so long even in scientirfic literature that the use of the term in this connection is somewhat justified by precedent and popularly this material is known by no other name. Cave onyx is essentially a marble of fine compact texture which has been deposited from solution by carbonate bearing waters. Its chief component is calcium carbonate, the proportion of which as shown by analyses rarely falls below 90%, while iron, either as oxide or carbonate, is next in importance, being present from a mere trace to 7% or 8%. This iron is responsible for most of the coloring of cave onyx although organic material and very fine insoluble clay particles may also contribute to the color.

Cave onyx is deposited in caverns in the form of stalactites, stalagmites and as incrustations upon the cave walls. Due to its manner of growth and the varying conditions under which it was formed onyx is composed of concentric or sub-parallel bands of different widths and colors, of which red browns and ochre reds

are most conspicuous, although dark brown, red, yellow and even green are not uncommon. This material is capable of retaining a high polish and is used chiefly for interior decorative purposes. Due to the irregularity and discontinuity of the deposits large pieces can seldom be obtained and much waste is inevitable. The market value of cave onyx depends directly upon the size of the polished slabs and the beauty of its coloring.

In a region where caves have been as extensively developed as in the southeastern part of Edmonson County considerable quantities of cave onyx are undoubtedly present. Exploration of the cave region of the county has never been undertaken with a view of the commercial production of this material. The financial returns which may be obtained from caves to which numerous tourists are attracted are many times greater than the value of the travertine contained in them and those caves which are of interest to the public either on account of their beauty or size should be preserved intact by all means. It is probable, however, that many of the small undiscovered or little explored caves of this region contain travertine deposits of considerable value which could be removed without destroying or in any way impairing the scenic wonders of the county generally. The mining of cave onyx is not ordinarily an enterprise to attract large capital on account of the occurrence of this material in small and irregular deposits but it might be undertaken by local individuals and some of the deposits might yield a profit under favorable marketing conditions.

Cement

The raw materials necessary for the manufacture of Portland cement are present in great abundance in Edmonson County. The shales of the Leitchfield Formation together with the interbedded or underlying limestone outcrop extensively at many localities. No analyses of these limestones are available but if it should be shown that they run low in magnesium they probably would be suitable for the production of first class cement. The situation is unfavorable at the present for the establishment of such an industry, however, because of lack of transportation and the distance from the large cities and industrial centers which are the most important consumers of this product.

Clays

Leitchfield Shales. The most important clay resources of Edmonson County from an economic standpoint are those which make up the shales of the Leitchfield Formation. Many years ago these clays became of interest because of their high potash content. Two analyses of shales taken near Leitchfield are given below:[6]

Alumina, iron and manganese oxides	19.133
Lime	.269
Magnesia	.353
Phosphoric acid	.267
Sulphuric acid	.027
Potash	2.910
Soda	.052
Water expelled at red heat	6.230
Silica and insoluble silicates	71.580
Total	100.821

This analysis was made after drying at 212° F. by digestion in acids, etc. The silica and insoluble silicates when sintered with calcium carbonate ammonium chloride, etc., yielded 1.205% of potash and .055% of soda in addition to the amounts stated above, so that the total amount of potash is 4.115% and that of soda .602%. Another sample analyzed by fusion with mixed alkali carbonates and sintering with calcium carbonate, ammonium chloride, etc., gave the following results:

Alumina					14.130
Iron and manganese oxides					13.480
Lime	.760	.480	.640	.680	.980
Magnesia	.560	no est.	no est.	no est.	.671
Phosphoric acid					.280
Sulphuric acid					.204
Potash					4.625
Soda					.783
Water, etc., expelled at red heat					6.000
Silica					60.060
Total					101.258

The above analyses show that the potash content is partly free and partly combined. This and similar shales would undoubtedly be of value as a fertilizer for tobacco fields, particularly where the soil is rather sandy. The potash content of the Leitchfield shales, however, is by no means constant, as is shown

[6] Robert Peter: "Chemical Report." Geol. Surv. Ky. N. S., Vol. 1, Pt. 4 (1876), pp. 220-221.

FIG. 55. WASHED LEITCHFIELD FORMATION.
Exposure of shale in the lower part of the Leitchfield Formation on the hillside above Green River just west of the mouth of Little Beaverdam Creek.

by the following analyses which were taken from various layers in an eight foot shale bed in Caney Hollow:

Silica	80.160	77.660	74.460	71.560	67.560
Alumina iron and manganese oxides	11.600	16.800	20.440	22.860	22.540
Lime	.760	.480	.640	.680	.980
Magnesia	.560	no est.	no est.	no est.	.671
Phosphoric acid	no est.	no est.	no est	no est.	.025
Potash	3.854	1.002	no est	no est.	2.470
Soda	.583	.484	no est	no est.	.058
Water and undetermined	2.483	4.340	4.460	4.900	5.696
Total	100.00	100.766	100.00	100.00	100.00

The possible value of the Lietchfield shales for fertilizer and as a material for the manufacture of paint has been stressed in several of the old reports of the Kentucky Survey. The possibility of their use as paints is dependent upon the bright colors of certain of the beds and their freedom from grit, and tests upon a small scale produced points which were highly resistant to

weathering. By far the most important use to which these clays might be put, however, is in the manufacture of ceramic products, but the absence of adequate transportation is at present an insurmountable difficulty.

Pennsylvanian Shales. Shales occurring in the Pennsylvanian System are even more widely distributed than those of the Leitchfield Formation. They occur chiefly in the northern part of the county in the neighborhood of Nolin River where the massive sandstone and conglomerate phases of the basal Pottsville are undeveloped, and farther to the west where beds higher in the system outcrop. These shales are probably of as good quality locally as those at the top of the underlying Chester, but in general they are inclined to be sandy and their sequence is often interrupted by numerous thin layers of sandstone. Investigation might reveal extensive deposits suitable for the manufacture of brick or other coarse ceramic products.

Residual Clays. Residual clays resulting from the disintegration of the Mississippian limestones are of common occurrence in the southern and eastern portions of Edmonson County. They are of a decidedly red color and are very tenaceous. No tests in regard to their burning qualities are known to have been made. These clays are probably of more value as soil than as a raw material for a manufacturing industry, as they invariably contain chert fragments intimately intermixed, the separation of which would be an expensive process.

Residual clays derived from the Pennsylvanian sediments are present upon many of the hill tops in the northern and western portions of the county. They are usually sandy and probably of little value. Clay of this type was formerly utilized near Bee Spring, where bricks were burned for local use.

Kaolin. Highly aluminous material having a composition somewhat similar to kaolin has been reported from two localities in Edmonson County. This material is rather soft and light, has a waxy appearance, breaks with a conchoidal fracture and varies in color from pure white to yellow, dark green and brown. The physical properties seem to ally this material to the indianaite variety of kaolin. At both localities where it has been observed, one located on the east side of Green River one and one-half miles south of Brownsville and the other on Indian

Creek several miles to the northwest, this material occurs near the contact between the Pottsville sandstone and the Leitchfield Formation. At the Indian Creek locality a bed 56 inches thick is reported[7] while at the southern occurrence there is a bed four or five feet in thickness[8] which overlies two feet of harder brownish material which may be a mixture of bauxite, wavellite and indianite.[9] Three analyses of these materials are given below:

	1	2	3
Moisture	5.15	6.84	13.65
Ignition (Combined water and volatile matter)	14.52	13.48	20.92
Silica	42.40	42.42	20.04
Alumina	36.21	35.20	40.53
Ferric oxide	.45	.64	1.24
Lime	.38	.34	.36
Magnesia	.53	.53	.40
Potash	.09	.23	.31
Soda	.08	.09	none
Phosphorus pentoxide	.20	.22	3.75
Titanium dioxide	trace	trace	trace
Sulphur dioxide	trace	trace	.27
Total	100.01	100.35	101.47

Numbers 1 and 2 are samples from the upper and lower parts of the bed at the southern locality while number 3 is an analysis of the hard brown material which occurs at the bottom of the same deposit.[9]

The indianaite of Indiana is similar in composition, texture and occurrence to the material which has been briefly described above and it has come to be of considerable economic importance both in the ceramic industry and in the manufacture of aluminum sulphate.[10] It is believed to have been produced by the action of sulphate bearing waters upon the constituents of shale and occurs in pockets or channels at the contact between the

[7] J. O. Bryant: "Economic Geology of a Portion of Edmonson and Grayson Counties." Ky. Geol. Surv., Ser. 4, Vol. 2, Pt. 1 (1914), p. 206.
[8] J. H. Gardner: "Clays in Several Parts of Kentucky." Ky. Geol. Surv. Bull. 6 (1905), p. 51.
[9] Bryant, in connection with his description of the Indian Creek occurrence, includes an analysis which he states was made from a sample taken by him out of a test pit at this locality. Comparison of this analysis with No. 3 above, which is after Gardner, reveals that the two are identical. The analysis given by Bryant cannot therefore have been made from the Edmonson County sample as indicated.
[10] Reeves: "Economic Geology of Indiana," in Handbook of Indiana Geology, Ind. Dept. Conserv. (1923).

Pennsylvanian sandstones and Chester shales. Careful search in Edmonson County may lead to the discovery of deposits of this type of kaolin of considerable value.

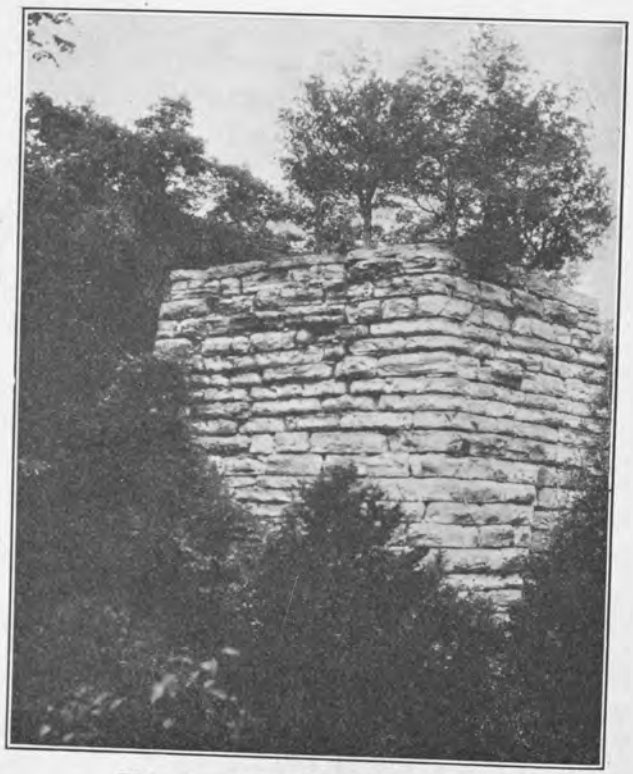


FIG. 56. OLD NOLIN FURNACE.
This stone structure was built in the middle fifties. It stands as a massive monument to a mineral industry which has all but been forgotten.

Iron

The iron ores of Edmonson County are at present of no economic importance but they are of interest historically. Kentucky was the pioneer iron producing state west of the Alleghenies, the first furnace being constructed near Owensville in 1790 and as late as sixty years ago this state ranked fourth in the Union in iron production. In the seventies a great deal of attention was paid by the Geological Survey of Kentucky to the iron ores of Edmonson County, and Shaler writes: "The work done

in Edmonson County alone, has shown the existence of a very extensive iron field, which can furnish exceedingly cheap, high grade ores to a hundred furnaces for a century to some."[11]

In 1844 or 1845 the Nolin Furnace was built near the mouth of Davis Creek and operated for three or four years, but was then shut down chiefly on account of difficulties encountered in transporting its product to the market. The furnace used charcoal for fuel and produced only cold blast iron, the analysis of a sample of which is given below.[12]

Iron	94.287
Graphic carbon	3.100
Combined carbon	.700
Silicon	.493
Phosphorus	1.092
Sulphur	.012
Total	99.611

The iron ores of Edmonson County are both limonites and siderites and are present in stratified beds entirely conformable with the associated strata. Probably most of both limonite and siderite is due to the oxidation of pyrite at one time disseminated through the Pennsylvanian beds. Observations have shown that the influence of the ground water circulation has been the controlling factor in the segregation of the iron, the ore in many places being both thicker and richer at the outcrop than a short distance under cover and in a few cases outcrops of limonite may grade into siderite beneath the hills. The presence of numerous highly chalybeate springs throughout the district indicates that this process is still in operation. The siderites occur in the shales of the Leitchfield Formation only a short distance below the Pottsville and also in certain Pennsylvanian shales. An analysis of siderite ore from a locality near the old Nolin Furnace is given below.[13] The exact position of this bed in the section is not known.

[11] N. S. Shaler: "Report of Progress." Geol. Surv. Ky. N. S., Vol. 3 (1877) p. 51.
[12] P. N. Moore: "Geology of the Nolin River District." Geol. Surv. Ky. Ser. 3, Vol. 2 (1877), p. 133.

Specific gravity 3.507
Dried at 212°, lost .50% of moisture

Carbonate of iron	65.13
Oxide of iron	7.98
Carbonate of lime	1.95
Carbonate of magnesia	8.45
Carbonate of manganese	1.83
Alumina	.95
Phosphoric acid	.36
Sulphuric acid	.67
Potash	.57
Soda	.05
Silex and insoluble silicates	9.17
Organic matter, moisture and loss	2.89
Total	100.00
Iron	37.04%
Sulphur	.10%

The limonite ores of Edmonson County occur in the Leitchfield Formation a short distance beneath the basal member of the Pottsville and also at a number of higher horizons in the more shaly parts of the Pennsylvanian beds. One of the purest limonite layers in the county occurs in the Chester shale along Gulf Creek not more than 20 feet below the Pottsville conglomerate. The limonite beds of the Pennsylvanian attain a possible maximum thickness of six feet and four foot beds are reported in some of the old reports of the Kentucky Survey at more than one locality. These beds vary from ferruginous sandstones to ores carrying over 50% of metallic iron. In texture they are sandy, conglomeratic, concretionary, oolitic or fossilferous. In the southern portion of the valley of Dismal Creek limonite is commonly associated with the conglomeratic phase of the basal Pottsville, the ore bed in this vicinity ranging from one to two feet in thickness. Two analyses of this ore are given below:

Peroxide or iron	55.028	47.724
Alumina	1.006	2.501
Brown oxide of manganese	0.040	.....
Lime	trace	trace
Magnesia	.108	trace
Phosphoric acid	.312	.065
Sulphuric acid	.133	.315
Combined water	8.300	8.250
Silica and insoluble silicates	35.180	40.145
Total	100.000	100.000
Metallic iron	35.519	33.407
Phosphorus	.135	.028
Sulphur	.053	.125
Silica	33.700	39.560

[13] Robert Peter: "Second Chemical Report," in Owen's Second Report of the Geological Survey in Kentucky (1857), p. 160.

The concretionary limonitic beds occur mainly in the shales in the lower part of the Pennsylvanian section in the northern part of the county where the basal conglomeratic sandstones are least developed. The concretions occur either scattered along certain horizons or grouped so closely together as to form a continuous pavement. These pavements are commonly from two to three inches in thickness and are formed of a perfect mosaic of concretions sharply polygonal in outline, rarely over eight inches in greatest dimension. The concretions themselves are composed of alternate dark brown brittle layers of limonite and softer red or yellow ochreous bands.

Moore reports the presence of an oolitic bed of limonite in the heads of Sycamore and Beaver Creeks at a horizon about 60 feet above the massive conglomerate. This oolitic ore is rather coarse grained and occurs in a bed over four feet in thickness which breaks into rectangular blocks. It contains about 35% of metallic iron and 30% of silica.

The old Proctor ore bank is located upon a hill lying between two branches of Sycamore Creek about two-thirds of a mile west of the Brownsville road. The ore at this place is apparently of a residual nature as it occurs in blocks upon the top and sides of the hill and no beds have ever been observed in place. This limonite is exceedingly fossiliferous and contains an unusually small percentage of silica. An analysis is as follows:

Peroxide of iron	76.282
Alumina	2.361
Brown oxide of manganese	.030
Lime	.180
Magnesia	.068
Phosphoric acid	1.055
Sulphuric acid	.151

Combined water	12.000
Silica and insoluble silicates	7.951
Total	100.080
Metallic iron	53.399
Phosphorus	.460
Sulphur	.059
Silica	7.660

The limonitic and sideritic beds occurring within Edmonson County are present at many different horizons and on the whole are of small lateral extent, none of them having been traced for more than two or three miles. It is thought that it would be quite impossible to secure cheaply adequate tonnages of iron ore in this county, such at least as would justify operation under present competitive conditions.

Nitrates.

During the War of 1812, rather extensive operations were undertaken in Mammoth Cave for the extraction of nitrates from the clays and silts present in some of the larger passages. Water was conducted into the cave through a wooden pipe line and the nitrates leached out of the cave deposits and used in the manufacture of gunpowder. Parts of the old pipe line and the leaching vats are still present in the cave where many thousands of people view them yearly. Nitrates of calcium, sodium and potassium are present in the cave deposits and are undoubtedly derived from the excretions of bats which formerly lived here in great numbers. Mammoth Cave apparently was not utilized during the Civil War as a source of saltpeter as were many of the caves of Tennessee. The percentage of nitrates in these deposits is rather small. Miller reports 2.2% of calcium and potassium nitrates in the earth of Hines Cave in Wayne County,[14] and a survey of the Tennessee caves during the World War with a view toward discovering a possible source of saltpeter revealed the maximum amount of nitrates to be 1.47%.[15] These percentages demonstrate that nitrates cannot be extracted profitably at the present from the cave deposits, but the material might prove to be of some value as a fertilizer, as it is said to contain in addition

[14] A. M. Miller: "Recent Cave Explorations in Kentucky." Ky. Geol. Surv., Ser. 6, Vol. 10 (1923), pp. 110-111.
[15] L. C. Glenn: "Discussion of the Chemical Analyses of the Cave Deposits of Tennessee." Res. Tenn., Vol. 8 (1918), pp. 139-142.

to the nitrates a small amount of phosphoric acid and a large proportion of acidity neutralizing calcium carbonate.[16]

Caves.

Although the caves of Edmonson County produce no mineral resources they attract many thousands of tourists annually and are a greater financial asset to the county at the present time than the production of any single commodity, whether from the fields, the forests or the earth, with the single exception of rock asphalt. Caves are a purely geological phenomenon, and because of their great economic importance in this region they may logically be included under the heading of economic geology and the geologist should direct his attention to the likelihood of the existence of other caves which remain to be discovered.

A glance at the map shows that the well known caves of Edmonson County are all located in a small corner of the Valley Sink Area in the southeastern part of the county. Mammoth Cave, which may be reached by two entrances, extends beneath one hill while Great Onyx, Great Crystal and Colossal Caves which are located upon the topographic map and Salts Cave which is not, all lie beneath the next hill to the northeast. The existence of these caves in the situations in which they occur is due directly to the geologic conditions which prevailed in this part of the county in the past and the geologic processes which were then in action.

The geologic map shows that conditions are essentially identical throughout the Valley Sink Area and the present surface features indicate that the same processes have been in operation. It is probable, therefore, and almost certain that extensive cave systems are present beneath the other ridges which intervene between the valley sinks, some of which may be as large and extensive as Mammoth Cave itself. On account of the natural concentration of drainage toward Green River the cave systems are probably most notably developed in the northern part of this area. The region about Elko seems to be favorably situated and exploration in the upper portions of the several small hollows might produce interesting and generally unexpected results. Another area worth investigating lies in the neighborhood of Cedar Hill School.

[16] A. M. Miller: Op. Cit.

CHAPTER XII.

BIBLIOGRAPHY.

The following is a selected list of titles which have been consulted in the preparation of this report.

Comparatively little has been published on the geology of Edmonson County. Those papers which are concerned to a large extent with the geology of this district are marked by double asterisks while single asterisks denote those in which some minor reference is made to the county. The remaining titles are included here on account of the bearing which they have upon certain problems encountered in this work.

1. Bede, J. W., "The Cycle of Subterranean Drainage as Illustrated in the Bloomington, Indiana, Quadrangle." Ind. Acad. Sci. Proc. 1910.

2.**Bryant, J. O., "Economic Geology of a Portion of Edmonson and Grayson Counties." Ky. Geol. Surv. Ser. 4 Vol. 2 Pt. 1, 1914.

3. Burroughs, W. G., "A Pottsville-Filled Channel in the Mississippian." Ky. Geol. Surv. Ser. 6 Vol. 10, 1923.

3A. Geography of the Western Coal field. Ky. Geol. Survey, Series VI, Vol. No. 24, 1924.

4. *Butts, C., "Mississippian Formations of Western Kentucky." Ky. Geol. Surv. 1917.

5. "Mississippian Series of Eastern Kentucky." Ky. Geol. Surv. Ser. 6 Vol. 7, 1922.

6. Crump, M. H., "Oolitic Limestone of Warren County." Ky. Geol. Surv. Ser. 4 Vol. 1 Pt. 2, 1913.

7.**"Kentucky Rock Asphalt." Ky. Geol. Surv. Ser. 4 Vol. 1 Pt. 2, 1913.

8. *Easton, H. D., "Technology of Kentucky Clays." Ky. Geol. Surv. Ser. 4 Vol. 1 Pt. 2, 1913.

9. *Gardner, J. H., "Clays in Several Parts of Kentucky." Ky. Geol. Surv. Ser. 3 Bull. 6, 1905.

10. Glenn, L. C., "Discussion of the Chemical Analyses of the Cave Deposits of Tennessee." Res. Ten. Vol 8, 1918.

11. Greene, F. C., "Caves and Cave Formation of the Mitchell Limestone." Ind. Acad. Sci. Proc., 1908.

12. Hays and Ulrich, "Columbia Folio." U. S. G. S. Geol. Atlas No. 95, 1903.

13. Hoeing, J. B., "Oil and Gas Sands of Kentucky." Ky. Geol. Surv. Ser. 3 Bull. 1, 1905.

14. *Jillson, W. R., "Oil and Gas Resources of Kentucky." Ky. Geol. Surv. Ser. 5 Bull 1, 1919.
15.**"Kentucky Rock Asphalt—The Ideal Road Surface." Ky. Geol. Surv. Ser. 6, Vol. 2, Paper II, 1921.
16.**"Bibliography of Mammoth Cave." Ky. Geol. Surv. Ser. 6, Vol. 10, 1923.
17. *"American Karst Country." Pan-Amer. Geol.. Vol. 42, 1924.
18. *"Kentucky Rock Asphalt." Pan-Amer. Geologist. Vol. XLI, No. 4, pp. 251-258, 6 Illust., 1 Map., May, 1924.
19.**"Mammoth Cave," pp. 11-22. Kentucky State Parks, Ky. Geol. Survey, Series VI, 1924.
20.**"Asphalt Coal," pp. 78-81, Vol. 1, Trans. Ky. Academy of Science, 1924.
21. Leith, C. K., Structural Geology." Rev. Ed., Henry Holt & Co., New York, 1923.
22. *Miller, A. M., "Geology of Kentucky." Ky. Geol. Surv. Ser. 5, Bull. 2, 1919.
23. "Recent Cave Explorations in Kentucky." Ky. Geol. Surv. Ser. 6, Vol. 10, 1923.
24.**Moore, P. N., "Geology of the Nolin River District." Geol. Surv. Ky. N. S. Vol. 2, Pt. 2, 1877.
25. "Geology of the Region Adjacent to the Eastern Border of the Western Coal Fields." Geol. Surv. Ky N. S. Vol. 4, Pt. 11, 1878.
26. Norwood, C. J., "Report on the Geology Adjacent to the Louisville, Paducah and Southwestern Railroad." Geol. Surv. Ky. N. S. Vol. 1, 1876.
27. *Owen, D. D., "Report on the Geological Survey in Kentucky." 1856.
28. *Peter, R., "Second Chemical Report," in Owen's Second Report of the Geological Survey in Kentucky, 1857.
29. *"Chemical Report." Geol. Surv. Ky. N. S. Vol 1, Pt. 4, 1876.
30. Reeves, , "Economic Geology of Indiana." In Handbook of Indiana Geology, Ind. Dept. Conserv., 1923.
31. *Richardson, C. H., "Building Stones of Kentucky." Ky. Geol. Surv. Ser. 6, Vol. 11, 1923.
32. *"Road Materials of Kentucky." Ky. Geol. Surv. Ser. 6, Vol. 22, 1924
33. *Ries, H., "Clay Deposits of Kentucky." Ky. Geol. Surv. Ser. 6, Vol. 8, 1922.
34. *Shaler, N. S., "Reports of Progress." Geol. Surv. Ky. N. S. Vol. 3, 1877.
35. Shaw, E. W., "Newly Discovered Beds of Extinct Lakes in Southern and Western Illinois and Adjacent States." Ill. State Geol. Surv., Bull. 20, 1915.
36. Shaw and Mather, "Oil Fields of Allen County, Kentucky." U. S. G. S., Bull. 688, 1919.
37. Veatch, A. C., "Notes on the Ohio Valley in Southern Indiana." Jour. Geol., Vol. 6, 1898.

38. Weller, S., "Stratigraphy of the Chester Group in Southwestern Illinois." Ill. Acad. Sci. Trans., Vol. 6, 1914.
39. "The Chester Series of Illinois." Jour. Geol., Vol. 28, 1920.
40. "Geology of the Princeton Quadrangle." Ky. Geol. Surv. Ser. 6, Vol. 10, 1923.

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